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ROYAL SIGNALS AND RADAR ESTABLISHMENT, MALVERN

DIAGNOSTIC RHYME TEST STATISTICAL ANALYSIS PROGRAMS

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ABSTRACT

This report describes the statistical techniques and associated computer programs employed to analyse data obtained from Diagnostic Rhyme Tests (DRT), and was previously published as a CC4 Divisional Memorandum. The conduct of the DRT (used for quantifying speech intelligibility) was described in RSRE Report No 87003.

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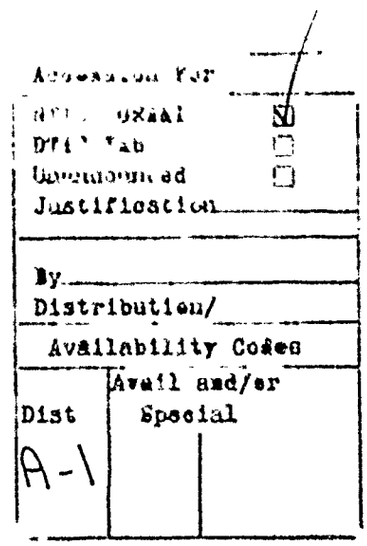

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1 INTRODUCTION

1.1 The Diagnostic Rhyme Test

The Diagnostic Rhyme Test (DRT) is used extensively for assessing the intelligibility of military communications systems and has become an accepted NATO standard for testing Linear Predictive Coders. A discussion of the acoustic and phonetic research on which the test is based is beyond the scope of this report, consequently only a brief outline of the test is given here.

The DRT vocabulary comprises ninety-six minimally contrasting rhyming word pairs, the initial consonants of which differ only by a single acoustic feature, or attribute. There are six such attributes; Voicing, Nasality, Sustention, Sibilation, Graveness and Compactness. As an example, the attribute voicing is present when the vocal cords are excited; in the word pair "veal-feel", the consonant "v" is voiced, but the consonant "f" is unvoiced.

The DRT is implemented using the following procedure. The 192 word vocabulary is first recorded by a set number of talkers, usually 5 or 10. A total of thirty different preordained word orders are available to eliminate possible learning effects by listening subjects. The microphone used to make the recordings and the ambient acoustic environment are selected according to the proposed operational deployment of the communication system under test. The recordings are then processed by passing them through the actual communication system (or a laboratory simulation if this is not possible) and re-recorded. The processed word lists are then presented aurally to a panel of listeners via the appropriate earphone transducer which is usually contained in a helmet, headset or handset. At the same time the listeners are also presented the appropriate word pair visually on a VDU. They then select the word they thought they heard by pressing one of two buttons. The intelligibility score is expressed as a proportion of the number of words correctly identified by the listeners, with the scores adjusted for chance so that a subject guessing will score 0% rather than 50%.

To ensure adequate stability of the results, tests are conducted using not less than five talkers and eight listeners. Each of the talkers utters the 192 word vocabulary at a rate of one word every 1.33 seconds; a five talker test therefore lasts approximately twenty-five minutes. Male and female subjects are recruited from the local population and paid for their participation as listeners in the tests which are normally conducted three mornings a week. The implementation is very close to that employed by US testing agencies, thereby allowing the exchange of speech material between the US and the UK for comparative assessment.

1.2 RSRE Implementation

The DRT system developed at RSRE involves a network of British Broadcasting Corporation (BBC) microcomputers comprising 12 listener

stations, a file-server and a master station, the listeners' VDUs being installed in two high-noise chambers. The listeners indicate their choice of word by pressing either the left or right button on a box connected to their microcomputer and the responses are logged at the master station. At the end of a listening session the results for all the listening subjects are amalgamated and stored in a text file known as a "condition" file. This file contains header information describing the test environment and blocks of user responses; each being signified by a '1' for a correct response and a '0' for an incorrect response.

The results can be analysed locally on a BBC microcomputer by running the program DRTSTAT, however the full package is available on a DEC VAX hardware in N building South Site. The terminal in the Acoustic Laboratory connected to the VAX is a BBC microcomputer running terminal emulation software. This means that the results held on a BBC formatted disc can be sent down the communications link to create text files on the VAX, which then act as input to the Analysis of Variance program, DRTSTAT.

1.3 Statistical Analysis

The DRT statistics package consists of three programs namely DRTSTAT, DRTFILE and DRTEDIT, which are run by typing @DRT1, @DRT2 and @DRT3 respectively at the VAX terminal.

@DRT1 takes a previously stored condition file and produces statistical analysis of the condition. It also stores the basic statistical (listener and talker identification, overall mark, attribute and individual listener scores) from every DRT experiment and stores the results in the file CONDMEANS.DAT.

@DRT2 reads CONDMEANS.DAT and takes user selected conditions and results from the analysis carried out by @DRT1 and reformats them for subsequent analysis by the program PANOVUN. This Analysis of Variance computer program is part of the suite of statistical analysis software supplied by the Institute of Aviation Medicine at Farnborough and is available on the VAX.

@DRT3 provides a facility to list and edit the running file of basic statistics updated by @DRT2.

1.4 Summary of Output from DRTSTAT

The statistical information output from the program was tailored to suit the particular requirements of the DRT experiments. This section describes the rationale behind the selection of the output. See Annex A for a sample printout.

1.4.1 Basic Statistics

The final result to be output is the overall mean score for the particular condition being tested along with the standard error of listeners scores when meaned over talkers. However it is also useful to be able to see, in tabular form, the performance of each individual listener/talker combination. This is output under the heading Individual Scores.

As has already been mentioned, the DRT tests the condition for six major attributes of speech. An output is therefore required which will show condition performance when each attribute was present and absent in the utterance. This is output under the heading Attribute Scores.

1.4.2 Analysis of Variance

Two way Analysis of Variance is designed to show the main and interactive effects of two factors, each factor having more than one level. In the case of DRT it was decided that the two main factors were Listeners and Talkers, with the list parts one and two being the replications. If the talker/listener interaction is shown not to be a significant effect then th Newman-Keuls test can be applied to listeners and talkers seperately.

1.4.3 Tukey Test for Nonaddativity

If the experiments were to be carried out on a single list (i.e. without replicatiCn), then the Tukey test for nonaddativity would be used to test the presence of a Talker X Listener interaction. If the test does not indicate the presence of an interaction, then the analysis of the main effects is carried out as described in the preceding section.

2 OPERATING INSTRUCTIONS

Note: @DRT1 requires the printer to be put on-line for hard copy before it is run.

@DRT2 will display messages as the required files are generated and allow immediate running of PANCVUN if desired.

@DRT1	Enter Condition Filename		Enter the name of the condition for analysis in the form CND9999
@DRT2	Enter Control Filename		Enter the name of the file containing the control information. (See Annex A.4 for example)
@DRT3	1	Display Index	Select option required
	2	Delete an Entry	
	3	End	

3 PROGRAM SPECIFICATIONS

3.1 @DRT1 Program Specification

It was decided that a total of five sets of analysis be carried out on the results of the DRT tests and their implementation along with a basic description is described below.

3.1.1 Tukey Test for Nonaddativity

If there is only one observation in each cell of a p*q factorial experiment there can be no within-cell variation and hence no direct estimate of experimental error. The following two models may be postulated to underlie the observed data:

(1) $X_{ij} = \mu + \alpha_i + \beta_j + \epsilon_{ij}$

(2) $X_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \epsilon_{ij}$

In (1) no interaction effect is postulated; hence all sources of variation other than main effects are considered to be part of the experimental error.

In (2) an interaction term is postulated. This interaction term may be considered as a measure of nonaddativity of the main effects.

Tukey developed a test applicable to the case in which there is a single observation per cell. The test is called a test for 'nonadditivity' and its purpose is to help in the decision between models (1) and (2). In his approach to the problem, Tukey starts with the model:

(3) $X_{ij} = \mu + \alpha_i + \beta_i + \lambda\alpha_i \beta_j + \epsilon_{ij}$

where $\alpha_i \beta_j$ is the product of the main effects and λ is a regression coefficient. here the product term is that part of the interaction which can be expressed as the product of main effects. A test in the hypothesis $\lambda = 0$ is equivalent to a test on the hypothesis that the product terms of this form do not contribute to the prediction of the X_{ij}.

In applying Tukey's test for nonadditivity to a p*q factorial experiment with one observation per cell, the analysis of variance takes the form:

Source of Variation	SS	d.f.	MS
A	SSa	p-1	MSa
B	SSb	q-1	MSb
Residual	SSres	(p-1)(q-1)	
Nonadditivity	SSnonadd	1	MSnonadd
Balance	SSbal	(p-1)(q-1)-1	MSbal

where SSbal = SSres - SSnonadd
and SSrea = SStotal SSa - SSb

The test for nonadditivity is given by:

F = MSnonadd / MSbal

When this F ratio exceeds the corresponding critical value, the hypothesis that model (1) (ie $\lambda = 0$) is appropriate is rejected. Tukey's test for nonadditivity is sensitive only to one source of nonadditivity - that associated with a component of interaction represented by $\alpha_i \beta_j$.

For full description of test see Winer - 'Statistical Principles In Experimental Design' pp 394-397.

Assuming a matrix of n listeners (i) by m talkers (j) and results X_{ij}, the equations are as follows:

$$SSa = (1/m) \cdot \sum_{i=1}^{n} (sum\ i)^2 - (1/(n \cdot m)) \cdot \left(\sum_i \sum_j X_{ij} \right)^2$$

$$SSb = (1/n) \cdot \sum_{i=1}^{n} (sum\ j)^2 - (1/(n \cdot m)) \cdot \left(\sum_i \sum_j X_{ij} \right)^2$$

$$SStotal = \sum_i \sum_j X_{ij}^2 - (1/(n \cdot m)) \cdot \left(\sum_i \sum_j X_{ij} \right)^2$$

SSres = SSab = SStotal - SSa - SSb

$$SSnonadd = \left(\left(\sum_i C_i D_i \right)^2 \right) / \left(\left(\sum_i C_i^2 \right) \cdot \left(\sum_j C_j^2 \right) \right)$$

SSbal = SSres - SSnonadd

MSx = (ssx) / (d.f.x)

Computational symbols

(6) $= 1/c \sum_{i=1}^{r} \left(\sum_{j=1}^{c} X_{ij} \right)^2$ (7) $= 1/r \sum_{j=1}^{c} \left(\sum_{i=1} X_{ij} \right)^2$

(8) $= 1/(r^{*}c) \left(\sum_{i} \sum_{j} X_{ij} \right)^2$ (9) $= \sum_{i} \sum_{j} X_{ij}^2$

(10) $= 1/c \sum_{j=1}^{c} X_{ij}$ (10) $= 1/(r^{*}c) \sum_{i} \sum_{j} X_{ij}$

(12) $= 1/r \sum_{i=1}^{r} X_{ij}$ (13) $= \sum_{j} (7)^{*}(6)$

Then:

SSlisners = (6) - (8)

SStalkers = (7) - (8)

SStotal = (9) - (8)

SSres = SStotal - SSlisners - SStalkers

3.1.2 Two Way Analysis of Variance

This analysis allows us to examine the combined effect of the two factors 'talkers' and 'listeners' ie the interactive effect. Replications in this case refer to parts 1 and 2 of the talker list. The form of the Analysis of variance is as follows:

Source	SS	d.f.	MS	F
Rows	SSr	(r-1)	SSr/(r-1)	MSr/MSerror
Columns	SSc	(c-1)	SSc/(c-1)	MSc/MSerror
RxC	SSrc	(r-1)(c-1)	SSrc/(r-1)(c-1)	
MSrc/MSerror				
Error	SSerr	rc(n-1)	SSerr/rc(n-1)	
Total	SStotal	rcn-1		

Computation of the various values is as follows:

	T1 ••••••••••••••••••• Tc	$R_i = \sum_j \sum_k X_{ijk}$
L1		•
•		•
•		•
•	X_{ijk}	•
•		•
•		•
Ln		•

$C_j = \sum_i \sum_j \sum_k$ ••••••••••••••••••••••• $G = \sum_i \sum_j \sum_k$

Computational symbols

(1) = G^2/rcn (2) = $\sum_i \sum_j \sum_k X_{ijk}^2$

(3) = $(\sum_i R_i^2) / cn$ (4) = $(\sum_j C_j^2) / rn$

(5) = $\left[\sum_i \sum_j \left(\sum_k X_{ijk}\right)^2\right] / n$ ie square each cells total and sum these:

Then:

SSr = (3) - (1)
SSc = (4) - (1)
SSrc = (5) - (3) - (4) + (1)
SSerror = (2) - (5)
SStotal = (2) - (1)

3.1.3 Newman-Keuls test

The Newman-Keuls test for the comparison of treatment means uses the 'Studentised Range Statistic', Qr. where r is the number of steps separating two means on an ordered scale.

Further explanation of the test will be given in terms of the DRT experiment involving six talkers and weight listeners. We shall for the moment consider the talkers, and investigate the difference between their means.

	T1	T2	T3	T4	T5	T6
L1						
L2						
•						
•						
•						
L8						
	$\bar{T}1$	$\bar{T}2$	$\bar{T}3$	$\bar{T}4$	$\bar{T}5$	$\bar{T}6$
posn	a	b	c	d	e	f

Fig 3.1

The Talker means should first be ranked $\bar{T}(1) \rightarrow \bar{T}(6)$ where $\bar{T}(1)$ is the smallest and $\bar{T}(6)$ the largest. $\bar{T}(6)$ is defined as being six steps from $\bar{T}(1)$. In general the number of steps between the ordered means is j-i+1.

Thus, $$Q6 = [\,\bar{T}(6) - \bar{T}(1)\,] \,/\, \sqrt{MSerror/n}$$

$n = 8$ *here* (16 *if* 2 *reps*)

There is only one Q6 statistic. There are however two Q5 statistics, namely:

$$Q5 = [\,\bar{T}(6) - \bar{T}(2)\,] \,/\, \sqrt{MSerror/n}$$

and

$$Q5 = [\,\bar{T}(5) - \bar{T}(1)\,] \,/\, \sqrt{MSerror/n}$$

Critical values for Qr are obtained from tables of the studentised range statistic by setting r equal to the range. For example, the critical value for Q6 in a 0.01-level test is Q.99 (6,f) where f is the degrees of freedom for MSerror.

In making a large number of test it is more convenient to obtain a critical value for the difference between two means:

$$\bar{T}(6) - \bar{T}(1) = QR \sqrt{MSerror/n}$$

The six talker means are designated by the symbols 'a' through to 'f',

and a new table is constructed with the talker means in ranked order across the top.

$\bar{T}_j$	$\bar{T}3$	$\bar{T}3$	$\bar{T}3$	$\bar{T}3$	$\bar{T}3$	$\bar{T}3$	'say'	
	c	a	d	b	f	e	r	val
c	-	$\bar{T}1-\bar{T}3$	$\bar{T}4-\bar{T}3$	$\bar{T}2-\bar{T}3$	$\bar{T}6-\bar{T}3$	$\bar{T}5-\bar{T}3$	6	x1 , say
a		-	$\bar{T}4-\bar{T}1$	$\bar{T}2-\bar{T}1$	$\bar{T}6-\bar{T}1$	$\bar{T}5-\bar{T}1$	5	x2
d			-	$\bar{T}2-\bar{T}4$	$\bar{T}6-\bar{T}4$	$\bar{T}5-\bar{T}4$	4	
b				-	$\bar{T}6-\bar{T}2$	$\bar{T}5-\bar{T}2$	3	
f					-	$\bar{T}5-\bar{T}6$	2	

where val = Q.99 (r,f) $\sqrt{MSerror/n}$

Fig 3.2

In general the entry in column j, row i is $\bar{T}_j - \bar{T}_i$. Only the entries shown in this table need be computed. It should be noted that entries on the same diagonal on the table have the same number of steps between each pair of means being compared.

There is a prescribed sequence in which tests on differences between ordered means should be made:

1 The first test is made on the difference in the upper right-hand corner. This is the difference for which r has its maximum value, which is in the case r = 6. Let the critical value for a 0.01-level test be x1. If $\bar{T}5-\bar{T}1$, ie $\bar{T}(6)-\bar{T}(1)$ does not exceed this value one need not carry out any further tests since, if there is no significant difference between the means furthest apart from each other, there will clearly be no significant difference between any pair of means closer together.

2 Tests are now made on all differences for which r = 5. If any of the difference values on the diagonal for which r = 5 do not exceed the critical value, say x2, no further tests are made on the triangular region defined by the rows and columns of which this particular difference forms the upper right-hand corner. For example, if $\bar{T}5-\bar{T}1 < x2$ there would be no need to test the following:

$\bar{T}4 - \bar{T}1$	$\bar{T}2 - \bar{T}1$	$\bar{T}6 - \bar{T}1$	
	$\bar{T}2 - \bar{T}4$	$\bar{T}6 - \bar{T}4$	$\bar{T}5 - \bar{T}4$
		$\bar{T}6 - \bar{T}2$	$\bar{T}5 - \bar{T}2$
			$\bar{T}5 - \bar{T}6$

Other entries on the diagonal, though, should be tested, eg $\bar{T}6 - \bar{T}3$, and the same eliminating procedure carried out where necessary. Thus we work through on the entries on the table given above.

The schematic representation of the significant differences between means of talkers take the form.

c a d b f e

Fig 3.3

The letters underlined by a common line are not significantly different to each other, ie there is no significant difference between $\bar{T}5$, $\bar{T}6$, $\bar{T}2$ and $\bar{T}4$, nor between $\bar{T}3$, $\bar{T}1$, $\bar{T}4$.

3.1.4 Attribute Scores

The DRT experiments are designed to examine the six major attributes which apply to consonant sounds of speech. These are:

Voicing
Nasality
Sustention
Sibilation
Graveness
Compactness

A table of mean and standard error of listeners scores is therefore required in the case where each of the six attributes were separately present and absent. Also included in the table is the mean and standard error of the combined present and absent scores.

3.1.5 Individual Scores and Overall DRT Score

The basic statistics of individual listeners scores are required for detailed examination of listeners performance and to allow

interpretation of, eg the Newman-Keuls test. The results are looked at from two 'directions', ie listener's score over talkers, and talker score over listeners.

The final statistic required is the overall DRT score and standard error.

To allow for archiving of results for further analysis certain values are stored in an indexed file, the key field being the condition number. The values stores are as follows:

Condition name
Listener's ID
Listener's mean scores
Listener's attribute scores
Talker results
Talker's ID
Number of talkers

3.2 @DRT2 Program Specification

In order to utilise the results saved by @DRT1, a program is required which will manipulate selected results into a form which can be processed by the statistics program PANOVUN. This format, known as EDA, is an Institute of Aviation Medicine standard.

Inputs:

1. Name of EDA file to be created.
2. Attributes required from conditions.
3. Conditions to be considered.
4. Particular listeners of interest.
5. Format of EDA file.
6. Design statements required for PANOVUN
7. List of all possible listener idents.

Outputs:

1. Data output files.
2. Messages to screen.

3.3 @DRT3 Program Specification

As the basic statistics from @DRT3 are automatically stores in a running file, it is necessary to be able to examine that file to see what Condition records are held. It is also necessary to be able to delete records in order to stop the file from becoming too large and overloaded with outdated information.

A program is required which will satisfy these requirements and also be written in such a way that will allow further editing facilities to be added in the light of changes in policy.

Input:

Either select Index of Conditions or Condition for deletion.

Output:

Either list of Condition numbers or notification of Condition deleted.

A1 PROGRAM DESCRIPTION

A1.1 @DRT1 Program Description

The command file prompts for the Condition file, copies it to DRTRES and runs the program DRTSTAT. As can be seen by reference to the structure chart, the program consists of eleven procedures which are described as below:

INITIALISE

1 Set 'Present or Absent' array to zero.

2 Set listener means array to zero.

3 Set listener ID array to '----' and talker ID array to '---'.

UPDATECONDMEANS

1 Collect condition name, listener and talker IDs, attribute scores, overall means, and talker results.

2 Open file.

3 If not stored by a previous run, store results using condition as key.

4 Close file.

READSEQFILE

1 Each DRT list has a different sequence in which the particular attribute being tested is present or absent. These sequences are read in from file into array SEQ.

READNKCONS

1 Read the file of constants required by the Newman-Keuls test.

READWRITE

1 Read the number of lines in parameter from DRTRES and output to printer.

READRESFIL

1 Reset DRTRES for reading

2 Read experiment ID

3 Read version number and output necessary number of lines.

4 Build up array of talker IDs.

5 If DYNASEQ was used then for each of the presentations in cnd file, calculate which SEQ applies.

6 Build up array of listener IDs.

7 Now that the first page of information has been read, the blocks of listener response can be read. The nesting is listeners within parts within talkers. Two results are calculated; the attribute scores and the overall scores. Attributes are only calculated if DYNASEQ is used. In which case, if a correct response is read (ie a '1') the sequence array is checked to find if the attribute was present or absent and the correct element in PORA incremented. The variable ATT cycles through the six attributes. Both the attributes and the overall results have the algorithm applied which gives a score of zero for completely random responses.

SINGLEREPS

1 Produces a matrix with the parts average for the Tukey test.

SETUNLNS

1 Build up the array ULNS which gives the number of dashes required for up to 12 positions from a left margin, ie pos 1 requires 1 dash, pos 3 requires 5. This is required when deciding how many elements in the Newman-Keuls test have to be underlined.

NKCALCS

1 Read in constants for calculating critical values.

2 Build up the array POSITIONARR.

3 If looking at talkers, CONV will contain numoflisners and vice-versa.

4 Sort the array of means (either listener or talker) into lowest to highest. Also sort the corresponding position in POSITIONARR.

5 Build up the values corresponding to Fig 3.2.

6 If no significant difference as in 3.3.1 the print out ordered means else ...

7 Carry out comparisons and calculate line lengths required (Fig 3.3).

8 Printout.

STATSONATTS

1 Calculate attribute means, sum of squares, and standard error.

2 Write results for attributes.

ANOVAR

1 Call READRESFIL; SINGLEREPS;

2 Calculate components required as in 3.1 and 3.2.

3 Write results for Tukey and ANOVA,

4 Calculate listener and talker means and call NKCALCS.

5 If DYNASEQ was used then call STATSONATTS.

6 Calculate individual means, grandmean, standard deviation, standard error for both listeners over talkers and talkers over listeners.

7 Write results for basic stats.

A1.2 @DRT2 Program Description

The command file prompts for the control file to be used and the name of the DRTFILE output file to be used as input to PANOVUN. It then runs DRTFILE followed by PANOVUN if desired. Whilst running, DRTFILE will report any errors it sees in the input data but whenever possible will allow the output file to be created. This is to allow the operator to ignore apparent errors for a particular requirement. As can be seen on the structure chart, DRTFILE consists of nine procedures and two functions as follows:

Function INTTOCHR

Takes integers in the range 0-99 and turns them into strings two characters long.

Function CHRTOINT

Takes strings of two characters and returns integers in the range 0-99.

Function TOCHARS

This function simply turns the real numbers stores on the file CONDMEANS into characters suitably formatted for the output text file.

1 If a score of 100% is encountered then write '100'else..

2 Check for sign to be inserted in first element of field.

3 Split the number into its character components.

4 Pack in into a string.

ENTERNAMES

1 Read the listener ids at the start if each data block and check to ensure that each 4 character name exists in the set of listener ids at the end of the control file. Build up an index of the listener id numbers.

UPDATE

Using recursion, update the parameters with the nested values for output.

OUTPTNESTING

Call UPDATE to find the latest values for the nestings and output them.

TOEDAFORM

Read the control file to find the format required for the EDA type file required by PANOVUN. After checking for errors and extracting the required information, write the header information to the output file. Cycle through the temporary file created earlier reading the listener names, extracting the required listeners results, checking for completeness, sorting and printing out the results to the output file. Finally add the required number of -1's.

DOEDAINPT

Read that part of the control file which contains the design statements for PANOVUN and write them to DRTEDA.

OUTDATA

1 Unpack string and pick our 3rd component.

2 Apply a hashing function to obtain a corresponding number for the attribute.

3 Relate the has number to the required value in PAORM and write the value after applying TOCHARS.

SELECTDATA

1 Write condition number and listener IDS.

2 Step through the string of attributes required and call OUTDATA for each until complete.

RETRIEVEREC

1 Locate required condition using cnd number as key.

2 If data located, generate attribute means and call SELECTDATA to pick out required elements.

DECODESTRGS

1 Find length of user input strings for conditions and attributes required.

2 Pick out each condition number and..

3 If a range has been specified, work out what each number would be in the range and call RETIEVEREC for each else..

4 Call RETRIEVEREC for condition number.

Main program

1 Open files.

2 Read input file and build up strings of attributes required and conditions.

3 Issue running message.

4 Call DECODESTRINGS.

5 If any of the conditions required do not exist then report and stop else...

6 Call TOEDAFORM to take DRTTMPFL1 and reformat it to DRTTMPFL2.

7 If any missing values exist then report.

8 Generate file of statements required for PANOVUN.

A1.3 @DRT3 Program Description

The command file runs the program DRTEDIT. This program only requires three procedures, ie DISPINDEX, DELENTRY and DISPMENU.

1 DISPINDEX opens the file for sequential access, reads each entry and displays the condition number.

2 DELENTRY opens the file for keyed access, find the required entry and deletes it from the file.

3 DISPMENU displays the options and the program CASE statement vectors to the required procedure.

```
DRT1.COM
$ WR:=WRITE SYS$OUTPUT
$ WR " "
$ WR "DRT STATISTICS PROGRAM"
$ WR "----------------------"
$ WR " "
$ AGAIN:
$ INQUIRE FILNAM "Enter filename"
$ SET NOON
$ COPY 'FILNAM' DRTRES.DAT
$ IF .NOT. $STATUS THEN GOTO AGAIN
$ SET ON
$ PURGE DRTRES.DAT
$ RUN DRTSTAT

DRT2.COM
$ DEASSIGN/ALL
$ SET TERM/WIDTH=132
$ SET TERM/NOWRAP
$ WR:=WRITE SYS$OUTPUT
$ WR " "
$ WR "DRT RESULTS REFORMATTER PROGRAM"
$ WR "-------------------------------"
$ WR " "
$ INQUIRE FILNAM "Enter Control Filename"
$ ASSIGN 'FILNAM' infile
$ ASSIGN DRTTMPFL2.DAT outfile
$ ASSIGN/USER_MODE 'F$LOGICAL("TT")' SYS$INPUT
$ PURGE DRTEDA.DAT
$ PURGE DRTTMPFL2.DAT
$ PURGE DRTTMPFL1.DAT
$ RUN DRTFILE
$ INQUIRE RUNPAN "Run Panovun? (Y/N)"
$ IF RUNPAN .EQS. "N" THEN GOTO done
$ PURGE DRTRESULTS.LIS
$ ASSIGN DRTRESULTS.LIS FOR013
$ DEASSIGN outfile
$ ASSIGN 'F$LOGICAL("TT")' FOR014
$ ASSIGN DRTTMPFL2.DAT FOR015
$ ASSIGN 'F$LOGICAL("TT")' FOR016
$ ASSIGN DRTONELINE.DAT FOR017
$ ASSIGN 'F$LOGICAL("TT")' FOR018
$ ASSIGN 'F$LOGICAL("TT")' FOR019
$ RUN PANOVUN
$ TYPE DRTRESULTS
$ done:
$ DEASSIGN/ALL

DRT3.COM
$ ASSIGN/USER_MODE SYS$COMMAND SYS$INPUT
$ RUN DRTEDIT
```

```
PROGRAM DRTSTAT(INPUT,OUTPUT,DRTRES,DRTCONS,CONDMEANS,DYNASEQ);

   (* RSRE Malvern 1985.                                        *)
   (* This program takes output from Diagnostic Rhyme Tests *)
   (* produced by Multi-Listener Master and performs the    *)
   (* statistical tests defined in the specification.       *)
   (* Although designed initially to run on a DEC VAX vers4,*)
   (* it has few Vax dependent features to allow easy       *)
   (* conversion for other PASCAL compilers.                *)

CONST
   NUMOFREPS=2;

TYPE
   STATABC4=ARRAY[1..12] OF REAL;
   ARROFMEANS=ARRAY[1..12] OF REAL;
   ARROFUNLNS=ARRAY[1..12] OF INTEGER;
   STRING=PACKED ARRAY[1..7] OF CHAR;
   STROFFOUR=PACKED ARRAY[1..4] OF CHAR;
   STROFTHREE=PACKED ARRAY[1..3] OF CHAR;
   CONDREC=RECORD
           CONDITION:[KEY(0)] PACKED ARRAY[1..7] OF CHAR;
           LNAMS:ARRAY[1..12] OF STROFFOUR;
           LISNEROAMS:ARROFMEANS;
           ATTRIBUTES:ARRAY[1..12,1..2,1..6] OF REAL;
           TLKRESMAT:ARRAY[1..12,1..12] OF REAL;
           TNAMS:ARRAY[1..12] OF STROFTHREE;
           TLKNUM:INTEGER;
          END;


VAR
   PORA:ARRAY[1..12,1..2,1..6] OF REAL;
   NUMOFTALKERS,NUMOFLISNERS,NUMOFPRES:INTEGER;
   DRTRES,DRTCONS,DYNASEQ:TEXT;
   DONE:BOOLEAN;
   OAM,GRANDMEAN,STANDEV,STANERR,OASTANERR:REAL;
   SSROW,SSCOL,SSROWCOL,SSERR,SSTOTAL,MSERR:REAL;
   OPTION,I,J,K:INTEGER;
   RESMAT:ARRAY[1..12,1..12,1..NUMOFREPS] OF REAL;
   SINREPMAT:ARRAY[1..12,1..12] OF REAL;
   SEQS:ARRAY[1..30,1..96,1..2] OF CHAR;
   RET:CHAR;
   UNLNS:ARROFUNLNS;
   LMEANS,TMEANS:ARROFMEANS;
   ATTMEAN:ARRAY[1..2,1..6] OF REAL;
   PAMEAN:ARRAY[1..6] OF REAL;
   NKCONS:STATABC4;
   EXPID:STRING;
   CONDMEANS:FILE OF CONDREC;
   OASTANDEV:REAL;
   LNRID:ARRAY[1..12] OF STROFFOUR;
   LNRIDARR:ARRAY[1..4] OF CHAR;
   TLKID:ARRAY[1..12] OF STROFTHREE;
```

```
   TLKIDARR:ARRAY[1..3] OF CHAR;
   NVAL:INTEGER;
   ATTSS:ARRAY[1..2,1..6] OF REAL;
   ATTSE:ARRAY[1..3,1..6] OF REAL;
   TITLSTR:PACKED ARRAY[1..66] OF CHAR;
   SUBTITL:PACKED ARRAY[1..11] OF CHAR;
   TITLPTR:INTEGER;
   MATTSS:ARRAY[1..6] OF REAL;
   SEQNUM:ARRAY[1..30] OF INTEGER;



PROCEDURE INITIALISE;
(* set arrays to 0 *)

   BEGIN
       FOR I:=1 TO 12 DO
           BEGIN
           FOR J:=1 TO 2 DO
               FOR K:=1 TO 6 DO
                   PORA[I,J,K]:=0;
           LMEANS[I]:=0;
           LNRID[I]:='----';
           TLKID[I]:='---'
           END;
   END;

PROCEDURE UPDATECONDMEANS;
(* add overall mean, lisners,attributes to file *)
   VAR
       COND:CONDREC;
   BEGIN
        WITH COND DO
        BEGIN
        CONDITION:=EXPID;
        FOR I:=1 TO 12 DO
            BEGIN
            LNAMS[I]:=LNRID[I];
            FOR J:=1 TO 2 DO
                FOR K:=1 TO 6 DO
                    ATTRIBUTES[I,J,K]:=PORA[I,J,K];
            LISNEROAMS[I]:=LMEANS[I];
            TLKNUM:=NUMOFTALKERS;
            FOR J:=1 TO NUMOFTALKERS DO
                TLKRESMAT[I,J]:=SINREPMAT[I,J]
            END;
        FOR I:=1 TO NUMOFTALKERS DO TNAMS[I]:=TLKID[I];
        END;
    OPEN(CONDMEANS,
         HISTORY:=UNKNOWN,
         ORGANIZATION:=INDEXED,
         ACCESS_METHOD:=KEYED);
    RESETK(CONDMEANS,0);
    FINDK(CONDMEANS,0,COND.CONDITION);
```

```
    IF UFB(CONDMEANS)
        THEN
        WRITE(CONDMEANS,COND)
        ELSE
        WRITELN('entry in CONDMEANS.DAT already exists');
    CLOSE(CONDMEANS);
    END;

PROCEDURE READSEQFILE;
(* create matrix of DYNA sequences for attributes *)
   VAR
       I,J,K:INTEGER;
       CH:CHAR;
   BEGIN
       RESET(DYNASEQ);
       FOR I:=1 TO 30 DO
           FOR K:=1 TO 2 DO
               BEGIN
               FOR J:=1 TO 96 DO
                   BEGIN
                   READ(DYNASEQ,CH);
                   SEQS[I,J,K]:=CH;
                   END;
               READLN(DYNASEQ);
               END;
   END;

PROCEDURE READNKCONS;
(* read file of constants for newman-keuls test *)
   BEGIN
       RESET(DRTCONS);
       FOR I:=2 TO 12 DO READLN(DRTCONS,NKCONS[I]);
   END;

PROCEDURE READWRITE(LINES:INTEGER);
(* read lines from drtres.dat and output to printer *)
VAR
    I:INTEGER;
    CH:CHAR;
    BEGIN
    FOR I:=1 TO LINES DO
        BEGIN
        WHILE NOT EOLN(DRTRES) DO
            BEGIN
            READ(DRTRES,CH);
            WRITE(CH);
            END;
        WRITELN;
        READLN(DRTRES);
        END;
    END;

PROCEDURE READRESFIL;
(* read drtres and build up matrices of results *)
```

```
VAR
   CH,VERS,AORB:CHAR;
   RIGHTS,WRONGS,L,OPLINES:INTEGER;
   NUMTLK,TOTPERATT:INTEGER;
   ATT,SEQJ:INTEGER;
   BEGIN
       FOR I:=1 TO 3 DO WRITELN;
       RESET(DRTRES);
       FOR I:=1 TO 14 DO BEGIN READ(DRTRES,CH); WRITE(CH);END;
       READLN(DRTRES,EXPID);
       WRITELN(EXPID);
       READLN(DRTRES);
       WRITELN;
       (* output experiment details *)
       FOR I:=1 TO 31 DO BEGIN READ(DRTRES,CH); WRITE(CH);END;
       READLN(DRTRES,VERS);
       WRITELN(VERS);
       IF VERS='1' THEN BEGIN
                        READWRITE(21);
                        FOR I:=1 TO 15 DO
                            BEGIN
                            READ(DRTRES,CH);
                            WRITE(CH);
                            END;
                        END
                   ELSE
                        BEGIN
                        READWRITE(18);
                        FOR I:=1 TO 6 DO
                            BEGIN
                            READ(DRTRES,CH);
                            WRITE(CH);
                            END;
                        END;
       READLN(DRTRES,NUMOFPRES);
       WRITELN(NUMOFPRES:3);
       READWRITE(1);
       (* read list numbers and calculate which row
          in matrix SEQ each presentation corresponds to *)
       NUMTLK:=0; SEQNUM[1]:=1000;(* tested later for attributes *)
       FOR I:=1 TO NUMOFPRES DO
           BEGIN
           IF I MOD 2 <> 0
           THEN (* build up talker id strings *)
               BEGIN
               NUMTLK:=NUMTLK+1;
               FOR J:=1 TO 3 DO
                   BEGIN
                   READ(DRTRES,TLKIDARR[J]);
                   WRITE(TLKIDARR[J])
                   END;
               PACK(TLKIDARR,1,TLKID[NUMTLK]);
               FOR J:=1 TO 13 DO BEGIN READ(DRTRES,CH);WRITE(CH) END
               END
```

```
    ELSE
        FOR J:=1 TO 16 DO BEGIN READ(DRTRES,CH);WRITE(CH) END;
    READ(DRTRES,CH);
    WRITE(CH);
    IF CH='.'
    THEN
        BEGIN
        READ(DRTRES,CH);
        WRITE(CH)
        END
    ELSE
        BEGIN
        SEQNUM[NUMTLK]:=ORD(CH)-48;
        READ(DRTRES,CH);
        WRITE(CH);
        SEQNUM[NUMTLK]:=10*SEQNUM[NUMTLK]+ORD(CH)-48;
        READ(DRTRES,AORB);
        IF AORB='B' THEN SEQNUM[NUMTLK]:=SEQNUM[NUMTLK]+15;
        WRITE(AORB);
        FOR J:=1 TO 2 DO BEGIN READ(DRTRES,CH);WRITE(CH);END;
        END;
    READLN(DRTRES);
    WRITELN;
    END;
READLN(DRTRES);
FOR I:=1 TO 10 DO BEGIN READ(DRTRES,CH); WRITE(CH);END;
READLN(DRTRES,NUMOFLISNERS);
WRITELN(NUMOFLISNERS:3);
READWRITE(1);
(* build up listener ID strings *)
FOR I:=1 TO NUMOFLISNERS DO
    BEGIN
    FOR J:=1 TO 4 DO
        BEGIN
        READ(DRTRES,LNRIDARR[J]);
        WRITE(LNRIDARR[J])
        END;
    PACK(LNRIDARR,1,LNRID[I]);
    WHILE NOT EOLN (DRTRES) DO BEGIN
                               READ(DRTRES,CH);
                               WRITE(CH);
                               END;
    READLN(DRTRES);WRITELN;
    END;
READLN(DRTRES);WRITELN;
WHILE NOT EOLN (DRTRES) DO READ(DRTRES,CH);
READLN(DRTRES);
NUMOFTALKERS:=NUMOFPRES DIV 2;
(* read 0 and 1's for each pres and build up results matrix *)
FOR J:=1 TO NUMOFTALKERS DO
   FOR K:=1 TO NUMOFREPS DO
       FOR I:=1 TO NUMOFLISNERS DO
           BEGIN
           FOR L:=1 TO 2 DO
```

```
                    BEGIN
                    WHILE NOT EOLN (DRTRES) DO READ(DRTRES,CH);
                    READLN(DRTRES);
                    END;
                RIGHTS:=0; WRONGS:=0;
                 SEQJ:=0; ATT:=0;
                FOR L:=1 TO 3 DO
                    BEGIN
                    WHILE NOT EOLN (DRTRES) DO
                   BEGIN
                        SEQJ:=SEQJ+1;
                        ATT:=ATT+1;
                        IF ATT=7 THEN ATT:=1;
                        READ(DRTRES,CH);
                        IF CH='1' THEN BEGIN
                                       RIGHTS:=RIGHTS+1;
                                       IF SEQNUM[1]<>1000 THEN
                                       IFSEQS[SEQNUM[J],SEQJ,K]='0'
                                          THEN PORA[I,1,ATT]:=
                                               PORA[I,1,ATT] + 1
                                          ELSE PORA[I,2,ATT]:=
                                               PORA[I,2,ATT] + 1;
                                       END
                             ELSE WRONGS:=WRONGS+1;
                      END;
                       READLN(DRTRES);
                 END;
                RESMAT[I,J,K]:=((RIGHTS-WRONGS)*100)/
                               (RIGHTS+WRONGS);
            END;

    (* apply conversion to attributes *)
    TOTPERATT:=NUMOFPRES * 8;
    FOR I:= 1 TO NUMOFLISNERS DO
        FOR J:=1 TO 2 DO
            FOR K:=1 TO 6 DO
                PORA[I,J,K]:=((2*PORA[I,J,K]-TOTPERATT)*100)
                                                  /TOTPERATT;
    END;

PROCEDURE SINGLEREPS;
(* average repetitions for tukey test *)
    BEGIN
        FOR I:=1 TO NUMOFLISNERS DO
            FOR J:=1 TO NUMOFTALKERS DO
               SINREPMAT[I,J]:=(RESMAT[I,J,1]+RESMAT[I,J,2])/2;
    END;

PROCEDURE SETUNLNS;
(* calculate underlining for NK test *)
VAR STEPS:INTEGER;
BEGIN
     STEPS:=1;
     FOR I:=1 TO 12 DO
```

```
        BEGIN
        UNLNS[I]:=STEPS;
        STEPS:=STEPS+2;
        END;
END;

PROCEDURE NKCALCS(TREATMEANS:ARROFMEANS;
                  TKLN:INTEGER);
(* newman-keuls test for listeners and talkers *)
LABEL
    99;
VAR
    CONV,DASHES,LINESUB,NUMTKLN,PREVIOUS,TEMP2:INTEGER;
    SIGDIFF,SORTED:BOOLEAN;
    TEMP,Q99MULT:REAL;
    NKMAT:ARRAY[1..12,1..13] OF REAL;
    LINELEN:ARRAY[1..40] OF INTEGER;
    POSITIONARR:ARRAY[1..12] OF INTEGER;
BEGIN
    READNKCONS;
    NUMTKLN:=TKLN;
    FOR I:=1 TO NUMTKLN DO POSITIONARR[I]:=I;
    CONV:=NUMOFTALKERS+NUMOFLISNERS-NUMTKLN;
    (* sort *)
    FOR I:=1 TO NUMTKLN DO
        BEGIN
            SORTED:=TRUE;
            FOR J:=1 TO (NUMTKLN-1) DO
                IF TREATMEANS[J]>=TREATMEANS[J+1] THEN
                    BEGIN
                    TEMP:=TREATMEANS[J];
                    TREATMEANS[J]:=TREATMEANS[J+1];
                    TREATMEANS[J+1]:=TEMP;
                       TEMP2:=POSITIONARR[J];
                       POSITIONARR[J]:=POSITIONARR[J+1];
                       POSITIONARR[J+1]:=TEMP2;
                    SORTED:=FALSE;
                    END;
        END;
    (* create matrix *)
    FOR I:=1 TO NUMTKLN-1 DO
        FOR J:=1 TO NUMTKLN-I DO
            NKMAT[I,J+I]:=TREATMEANS[J+I]-TREATMEANS[I];
    (* calculate constant table multiplier *)
    Q99MULT:=SQRT(MSERR/(NUMOFREPS*CONV));
    (* ammend matrix to contain 999 for ** in Winer *)
    IF NKMAT[1,NUMTKLN]<(NKCONS[NUMTKLN]*Q99MULT)
    (* i.e. if no sigdiff in top right of matrix *)
    (*      then print 1 - numtkln and underline *)
    THEN
        BEGIN
        WRITE(' ');
        FOR I:=1 TO NUMTKLN DO WRITE(POSITIONARR[I]:2);
        WRITELN;
```

```
        WRITE('  ');
            FOR I:=1 TO NUMTKLN*2-1 DO WRITE('-');
        END
   ELSE
        BEGIN
        NKMAT[1,NUMTKLN]:=999;
        FOR I:=2 TO NUMTKLN-1 DO
            FOR J:=0 TO I-1 DO
                IF NKMAT[I-J,NUMTKLN-J] >
                  (NKCONS[NUMTKLN+1-I]*Q99MULT)
                THEN NKMAT[I-J,NUMTKLN-J]:=999;
    (* set up underlines *)
        FOR I:=1 TO NUMTKLN-1 DO
            BEGIN
            LINELEN[I]:=1;
            FOR J:=I+1 TO NUMTKLN DO
                BEGIN
                (* count non-sigdiffs *)
                IF NKMAT[I,J] <> 999
               THEN LINELEN[I]:=LINELEN[I]+1
               ELSE GOTO 99;
                END;
99:         END;
        (* printout *)
        WRITELN;
        WRITE(' ');
        FOR I:=1 TO NUMTKLN DO WRITE(POSITIONARR[I]:2);
        WRITELN;
        SETUNLNS;
        DASHES:=1;
            PREVIOUS:=1;
        FOR I:=1 TO NUMTKLN-1 DO
            BEGIN
            IF LINELEN[I] <> 1 THEN
               BEGIN
               FOR J:=1 TO DASHES DO WRITE('  ');
                IF (2*DASHES)+UNLNS[LINELEN[I]]<>PREVIOUS THEN
                FOR J:=1 TO UNLNS[LINELEN[I]] DO WRITE('-');
               WRITELN;
               END;
            PREVIOUS:=(2*DASHES)+UNLNS[LINELEN[I]];
            DASHES:=DASHES+1;
            END;
      END;
   END;
PROCEDURE CALCLMEANS;
VAR
   MEANSTOT:REAL;
BEGIN
(* calc means for N.K. *)
FOR I:=1 TO NUMOFLISNERS DO
    BEGIN
    MEANSTOT:=0;
    FOR J:=1 TO NUMOFTALKERS DO
```

```
        MEANSTOT:=MEANSTOT+SINREPMAT[I,J];
    LMEANS[I]:=MEANSTOT/NUMOFTALKERS;
    END;
END;
PROCEDURE CALCTMEANS;
VAR
   MEANSTOT:REAL;
BEGIN
(* calc tmeans for N.K. *)
FOR J:=1 TO NUMOFTALKERS DO
    BEGIN
    MEANSTOT:=0;
    FOR I:=1 TO NUMOFLISNERS DO
        MEANSTOT:=MEANSTOT+SINREPMAT[I,J];
    TMEANS[J]:=MEANSTOT/NUMOFLISNERS;
    END;
END;
PROCEDURE STATSONATTS;
BEGIN
    (* stats on attributes *)
    FOR J:=1 TO 2 DO
        FOR K:=1 TO 6 DO
            BEGIN
            ATTMEAN[J,K]:=0;
            ATTSS[J,K]:=0;
            MATTSS[K]:=0
            END;
    FOR J:=1 TO 2 DO
        FOR K:=1 TO 6 DO
            BEGIN
            FOR I:=1 TO NUMOFLISNERS DO
                BEGIN
               ATTMEAN[J,K]:=ATTMEAN[J,K]+PORA[I,J,K];
               ATTSS[J,K]:=ATTSS[J,K]+SQR(PORA[I,J,K]);
               END;
            ATTMEAN[J,K]:=ATTMEAN[J,K]/NUMOFLISNERS;
            END;
    (* mean of P or A *)
    FOR K:=1 TO 6 DO
        PAMEAN[K]:=(ATTMEAN[1,K]+ATTMEAN[2,K])/2;
    (* SS of P or A *)
    FOR K:=1 TO 6 DO
        FOR I:=1 TO NUMOFLISNERS DO
            FOR J:=1 TO 2 DO
                MATTSS[K]:=MATTSS[K]+SQR(PORA[I,J,K]);
    (* SE of P or A *)
    FOR I:=1 TO 2 DO
           FOR J:=1 TO 6 DO
            IF NUMOFLISNERS=1
            THEN
               ATTSE[I,J]:=0
            ELSE
            ATTSE[I,J]:=SQRT((ATTSS[I,J]-NUMOFLISNERS*SQR(ATTMEAN[I,J])
                        )/(NUMOFLISNERS*(NUMOFLISNERS-1)));
```

```
    (* SE of means of P and A *)
    NVAL:=NUMOFLISNERS*2;
    IF NUMOFLISNERS>1 THEN
    FOR J:=1 TO 6 DO
        ATTSE[3,J]:=SQRT((MATTSS[J]-NVAL*SQR(PAMEAN[J]))
                        /(NVAL*(NVAL-1)));
    (* printout *)
TITLSTR:='Voicing       Nasality     Sustention  Sibilation  Graveness
Compactness';
TITLPTR:=1;
FOR I:=1 TO 4 DO WRITELN;
WRITELN('      ATTRIBUTE SCORES');
WRITELN('      ----------------');
WRITELN; WRITELN;
WRITELN('                    Present        Absent         Mean');
WRITELN('                  mean   SE     mean   SE     mean   SE');
WRITELN;
    FOR I:=1 TO 6 DO
        BEGIN
        SUBTITL:=SUBSTR(TITLSTR,TITLPTR,11);
        WRITELN(SUBTITL,'  ',ATTMEAN[1,I]:8:1,ATTSE[1,I]:6:1,
                ATTMEAN[2,I]:8:1,ATTSE[2,I]:6:1,PAMEAN[I]:8:1,
                ATTSE[3,I]:6:1);
        TITLPTR:=TITLPTR+11;
        END;
    END;

PROCEDURE ANOVAR;
(* main statistics calculation and output routine *)
       VAR
          G,TOT3,TOT4,TOT5,TOT6,TOT7,TOT8,TOT9:REAL;
          TOT3SUB1,TOT4SUB1,TOT6SUB,TOT7SUB:REAL;
          GRANDTOT,SDTOT:REAL;
          NONADDQUOT,NONADDSUB1,NONADDSUB2,NONADDIV:REAL;
          SSNONADD,SSBAL,MSBAL,SSRES:REAL;
          MSROW,ROWRAT,MSCOL,COLRAT,MSROWCOL,ROWCOLRAT:REAL;
          LISNDF,TALKDF,LNTKDF,ERRDF,TOTDF,BALDF:INTEGER;
          COMPNT:ARRAY[1..12] OF REAL;
          COMPNT10:ARRAY[1..12] OF REAL;
          TSSROW,TSSCOL,TMSROW,TMSCOL:REAL;
          COMPNT12:ARRAY[1..12] OF REAL;
          SDLN,SDTK:ARRAY[1..12] OF REAL;     BEGIN
           G:=0;COMPNT[2]:=0;TOT3:=0;TOT4:=0;TOT5:=0;
           FOR I:=1 TO NUMOFLISNERS DO
               BEGIN
                   TOT3SUB1:=0;
                   FOR J:=1 TO NUMOFTALKERS DO
                       BEGIN
                       TOT3SUB1:=TOT3SUB1
                                 +RESMAT[I,J,1]+RESMAT[I,J,2];
                       TOT5:=TOT5+
                           (RESMAT[I,J,1]+RESMAT[I,J,2])**2;
                       FOR K:=1 TO NUMOFREPS DO
                           BEGIN
```

```
                    G:=G+RESMAT[I,J,K];
                    COMPNT[2]:=COMPNT[2]+
                              RESMAT[I,J,K]**2;
                    END;
                END;
                TOT3:=TOT3+TOT3SUB1**2;
            END;
        (* build components required in specification *)
        COMPNT[1]:=G**2/(NUMOFLISNERS*NUMOFTALKERS
                                    *NUMOFREPS);
        COMPNT[3]:=TOT3/(NUMOFTALKERS*NUMOFREPS);
        COMPNT[5]:=TOT5/NUMOFREPS;
        TOT4:=0;
        FOR J:=1 TO NUMOFTALKERS DO
            BEGIN
            TOT4SUB1:=0;
            FOR I:=1 TO NUMOFLISNERS DO
                BEGIN
                TOT4SUB1:=TOT4SUB1+RESMAT[I,J,1]
                          +RESMAT[I,J,2];
                END;
            TOT4:=TOT4+TOT4SUB1**2;
            END;
        COMPNT[4]:=TOT4/(NUMOFLISNERS*NUMOFREPS);
            SSROW:=COMPNT[3]-COMPNT[1];
        SSCOL:=COMPNT[4]-COMPNT[1];
        SSROWCOL:=COMPNT[5]-COMPNT[3]-COMPNT[4]+COMPNT[1];
        SSERR:=COMPNT[2]-COMPNT[5];
        SSTOTAL:=COMPNT[2]-COMPNT[1];
        LISNDF:=NUMOFLISNERS-1;
        TALKDF:=NUMOFTALKERS-1;
        LNTKDF:=LISNDF*TALKDF;
        ERRDF:=NUMOFLISNERS*NUMOFTALKERS*(NUMOFREPS-1);
        TOTDF:=NUMOFLISNERS*NUMOFTALKERS*NUMOFREPS-1;
        MSROW:=SSROW/LISNDF;
        MSCOL:=SSCOL/TALKDF;
        MSROWCOL:=SSROWCOL/LNTKDF;
        MSERR:=SSERR/ERRDF;
        ROWRAT:=MSROW/MSERR;
        COLRAT:=MSCOL/MSERR;
        ROWCOLRAT:=MSROWCOL/MSERR;
(* Tukey Test for Nonadditivity *)
SINGLEREPS;
TOT6:=0; TOT8:=0; TOT9:=0;
FOR I:=1 TO NUMOFLISNERS DO
    BEGIN
        TOT6SUB:=0;
        FOR J:=1 TO NUMOFTALKERS DO
            BEGIN
            TOT6SUB:=TOT6SUB+SINREPMAT[I,J];
            TOT8:=TOT8+SINREPMAT[I,J];
            TOT9:=TOT9+SINREPMAT[I,J]**2;
            END;
        TOT6:=TOT6+TOT6SUB**2;
```

```
            COMPNT10[I]:=TOT6SUB/NUMOFTALKERS;
            END;
        COMPNT[6]:=TOT6/NUMOFTALKERS;
        COMPNT[8]:=TOT8**2/(NUMOFLISNERS*NUMOFTALKERS);
        COMPNT[9]:=TOT9;
        COMPNT[11]:=TOT8/(NUMOFLISNERS*NUMOFTALKERS);
        TOT7:=0;
        FOR J:=1 TO NUMOFTALKERS DO
            BEGIN
                TOT7SUB:=0;
                FOR I:=1 TO NUMOFLISNERS DO
                    BEGIN
                TOT7SUB:=TOT7SUB+SINREPMAT[I,J];
                    END;
                TOT7:=TOT7+TOT7SUB**2;
                COMPNT12[J]:=TOT7SUB/NUMOFLISNERS;
                END;
        COMPNT[7]:=TOT7/NUMOFLISNERS;
        TSSROW:=COMPNT[6]-COMPNT[8];
        TSSCOL:=COMPNT[7]-COMPNT[8];
        SSRES:=COMPNT[9]-COMPNT[6]-COMPNT[7]+COMPNT[8];
        (* Calc Nonadditivity *)
        NONADDQUOT:=0; NONADDSUB2:=0;
        FOR I:=1 TO NUMOFLISNERS DO
            BEGIN
            NONADDSUB1:=0 ;
                FOR J:=1 TO NUMOFTALKERS DO
                    BEGIN
                    NONADDSUB1:=NONADDSUB1+(COMPNT12[J]-COMPNT[11])
                                    *SINREPMAT[I,J];
                END;
                NONADDSUB2:=NONADDSUB2+(COMPNT10[I]-COMPNT[11])**2;
                NONADDQUOT:=NONADDQUOT+NONADDSUB1
                                *(COMPNT10[I]-COMPNT[11]);
            END;
        NONADDQUOT:=NONADDQUOT**2;
        NONADDIV:=0;
        FOR J:=1 TO NUMOFTALKERS DO
            BEGIN
            NONADDIV:=NONADDIV+(COMPNT12[J]-COMPNT[11])**2;
            END;
        IF NONADDIV = 0 THEN NONADDIV:= 0.001;
        NONADDIV:=NONADDSUB2*NONADDIV;
        SSNONADD:=NONADDQUOT/NONADDIV;
        SSBAL:=SSRES-SSNONADD;
        BALDF:=LNTKDF-1;
        TMSROW:=TSSROW/LISNDF;
        TMSCOL:=TSSCOL/TALKDF;
        MSBAL:=SSBAL/BALDF;
    FOR I:=1 TO 12 DO WRITELN(' ');
    WRITELN('      TUKEY TEST FOR NONADDATIVITY');
    WRITELN('      ---------------------------');
    FOR I:=1 TO 3 DO WRITELN;
    WRITELN('Source         Sum of    Degrees of    Mean ');
```

```
WRITELN('              Squares    Freedom      Square');
WRITELN(' ');
WRITELN('LISNERS ',TSSROW:13:2,LISNDF:10,TMSROW:13:2);
WRITELN('TALKERS ',TSSCOL:13:2,TALKDF:10,TMSCOL:13:2);
WRITELN('RESIDUAL',SSRES:13:2,LNTKDF:10);
WRITELN('NONADD  ',SSNONADD:13:2,'         1',SSNONADD:13:2);
WRITELN('BALANCE ',SSBAL:13:2,BALDF:10,MSBAL:13:2);
FOR I:=1 TO 5 DO WRITELN;
WRITELN('      ANALYSIS OF VARIANCE');
WRITELN('      --------------------');
WRITELN(' ');WRITELN(' ');
WRITELN('Source         Sum of    Degrees of    Mean',
        '     F-Ratio');

WRITELN('              Squares    Freedom      Square');
WRITELN(' ');
WRITELN('LISNERS ',SSROW:13:2,LISNDF:10,MSROW:13:2,ROWRAT:11:2);
WRITELN('TALKERS ',SSCOL:13:2,TALKDF:10,MSCOL:13:2,COLRAT:11:2);
WRITELN('LN * TK ',SSROWCOL:13:2,LNTKDF:10,MSROWCOL:13:2,
                                                ROWCOLRAT:11:2);
WRITELN('ERROR   ',SSERR:13:2,ERRDF:10,MSERR:13:2);
WRITELN('TOTAL   ',SSTOTAL:13:2,TOTDF:10);
(* Newman - Keuls Test *)
FOR I:=1 TO 4 DO WRITELN;
WRITELN('      NEWMAN - KEULS TEST');
WRITELN('      -------------------');WRITELN;
WRITELN('LISTENERS :');WRITELN;
NKCALCS(LMEANS,NUMOFLISNERS);
WRITELN;WRITELN;WRITELN('TALKERS :');
NKCALCS(TMEANS,NUMOFTALKERS);
IF SEQNUM[1]<>1000 THEN STATSONATTS;
(* calculate treatment means for basic stats *)
SDTOT:=0;GRANDTOT:=0;
FOR I:=1 TO NUMOFLISNERS DO
    BEGIN
    SDLN[I]:=0;
    FOR J:=1 TO NUMOFTALKERS DO
        SDLN[I]:=SDLN[I]+SINREPMAT[I,J]**2;
    SDLN[I]:=SQRT(ABS(SDLN[I]-NUMOFTALKERS*(LMEANS[I])**2)
                                        /(NUMOFTALKERS-1));
    SDTOT:=SDTOT+(LMEANS[I])**2;
    GRANDTOT:=GRANDTOT+LMEANS[I];
    END;
GRANDMEAN:=GRANDTOT/NUMOFLISNERS;
STANDEV:=SQRT(ABS(SDTOT-NUMOFLISNERS*GRANDMEAN**2)
                                    / (NUMOFLISNERS-1));
OASTANDEV:=STANDEV;
STANERR:=STANDEV/SQRT(NUMOFLISNERS);
FOR I:=1 TO 10 DO WRITELN;
WRITELN('      INDIVIDUAL SCORES');
WRITELN('      -----------------');
FOR I:=1 TO 3 DO WRITELN;
WRITE('LNR   T1');
FOR I:=2 TO NUMOFTALKERS DO WRITE('    T',I:1);
```

```
WRITE('   SD');
WRITELN;
FOR I:=1 TO NUMOFLISNERS DO
    BEGIN
    WRITE(I:2);
    FOR J:=1 TO NUMOFTALKERS DO WRITE(SINREPMAT[I,J]:6:1);
    WRITE(SDLN[I]:6:1);
    WRITELN;
    END;
WRITELN;
WRITELN('LNR   MEAN OVER TKR');
FOR I:=1 TO NUMOFLISNERS DO
    WRITELN(I:2,LMEANS[I]:13:1);
WRITELN;
WRITELN('STD. DEVN. =',STANDEV:5:1);
WRITELN('STD. ERROR =',STANERR:5:1);
OASTANERR:=STANERR;
SDTOT:=0;
FOR J:=1 TO NUMOFTALKERS DO
    BEGIN
    SDTK[J]:=0;
    FOR I:= 1 TO NUMOFLISNERS DO
        SDTK[J]:=SDTK[J]+SINREPMAT[I,J]**2;
    SDTK[J]:=SQRT((SDTK[J]-NUMOFLISNERS*TMEANS[J]**2)
                                        /(NUMOFLISNERS-1));
    SDTOT:=SDTOT+(TMEANS[J])**2;
    END;
STANDEV:=SQRT((SDTOT-NUMOFTALKERS*GRANDMEAN**2)
                            / (NUMOFTALKERS-1));
STANERR:=STANDEV/SQRT(NUMOFTALKERS);
FOR I:=1 TO 5 DO WRITELN;
WRITE('TKR   L1');
FOR I:=2 TO NUMOFLISNERS DO
    IF I<10 THEN WRITE('    L',I:1) ELSE WRITE('   L',I:1);
WRITE('   SD');
WRITELN;
FOR I:=1 TO NUMOFTALKERS DO
    BEGIN
    WRITE(I:2);
    FOR J:=1 TO NUMOFLISNERS DO WRITE(SINREPMAT[J,I]:6:1);
    WRITE(SDTK[I]:6:1);
    WRITELN;
    END;
WRITELN;
WRITELN('TKR   MEAN OVER LNR');
FOR I:=1 TO NUMOFTALKERS DO
    WRITELN(I:2,TMEANS[I]:13:1);
WRITELN;
WRITELN('STD. DEVN. =',STANDEV:5:1);
WRITELN('STD. ERROR =',STANERR:5:1);
FOR I:=1 TO 5 DO WRITELN;
WRITELN('     DRT SCORE =',GRANDMEAN:5:1);
WRITELN('STANDARD ERROR =',OASTANERR:5:1);
FOR I:=1 TO 5 DO WRITELN;
```

```
END;

PROCEDURE BASIC_AND_ATT_STATS;

BEGIN
IF SEQNUM[1] <>1000 THEN STATSONATTS;
FOR I:= 1 TO 10 DO WRITELN;
WRITELN('      INDIVIDUAL SCORES');
WRITELN('      -----------------');
FOR I:=1 TO 3 DO WRITELN;
WRITE('LNR');
FOR I:=1 TO NUMOFTALKERS DO WRITE('    T',I:1);
WRITELN;
FOR I:=1 TO NUMOFLISNERS DO
    BEGIN
    WRITE(I:2,'  ');
    FOR J:=1 TO NUMOFTALKERS DO WRITE(SINREPMAT[I,J]:6:1);
    WRITELN;
    END;
WRITELN;
WRITELN('LNR   MEAN OVER TKR');
FOR I:=1 TO NUMOFLISNERS DO
    WRITELN(I:2,LMEANS[I]:13:1);
WRITELN;
FOR I:=1 TO 5 DO WRITELN;
WRITE('TKR');
FOR I:=1 TO NUMOFLISNERS DO
    WRITE('    L',I:1);
WRITELN;
FOR I:=1 TO NUMOFTALKERS DO
    BEGIN
    WRITE(I:2,'  ');
    FOR J:=1 TO NUMOFLISNERS DO WRITE(SINREPMAT[J,I]:6:1);
    WRITELN;
    END;
WRITELN;
WRITELN('TKR   MEAN OVER LNR');
FOR I:=1 TO NUMOFTALKERS DO
    WRITELN(I:2,TMEANS[I]:13:1);
WRITELN;
GRANDMEAN:=0;
FOR J:=1 TO NUMOFTALKERS DO
    GRANDMEAN:=GRANDMEAN + TMEANS[J];
GRANDMEAN:=GRANDMEAN/NUMOFTALKERS;
FOR I:=1 TO 5 DO WRITELN;
WRITELN('DRT SCORE = ',GRANDMEAN:5:1);
FOR I:=1 TO 5 DO WRITELN;
END;


(* Main Program *)
BEGIN
    WRITELN;
    FOR I:=1 TO 3 DO WRITELN;
```

```
INITIALISE;
READSEQFILE;
READRESFIL;
SINGLEREPS;
CALCLMEANS;
CALCTMEANS;
IF (NUMOFTALKERS > 2) AND
   (NUMOFLISNERS > 2)
   THEN ANOVAR
ELSE  BASIC_AND_ATT_STATS;
UPDATECONDMEANS;
END.
```

```
PROGRAM DRTFILE(INPUT,OUTPUT,AFL,BFL,DRTTMPFL1,DRTEDA,CONDMEANS);

(* Input:      Data from the file Condmeans created *)
(*             by DRTSTAT.                          *)
(* Processing: Extract required results, transpose  *)
(*             into chars, reformat and store for   *)
(*             subsequent use by PANOVUN.           *)

CONST
    CREWNAMES=100;
    DEPTHOFNESTING=15;
    MAXDATASTRG=100;
    MAXTITLESTRG=100;

TYPE
    ARROFMEANS=ARRAY[1..12] OF REAL;
    STROFTWO=PACKED ARRAY[1..2] OF CHAR;
    CONDTYP=PACKED ARRAY[1..4] OF CHAR;
    ATTYP=PACKED ARRAY[1..3] OF CHAR;
    REALCHRS=PACKED ARRAY[1..5] OF CHAR;
    NAMTYP=PACKED ARRAY[1..6] OF CHAR;
    STROFTHREE=PACKED ARRAY[1..3] OF CHAR;
    CONDREC=RECORD
            CONDITION:[KEY(0)] PACKED ARRAY[1..7] OF CHAR;
            LNAMS:ARRAY[1..12] OF CONDTYP;
            LISNEROAMS:ARROFMEANS;
            ATTRIBUTES:ARRAY[1..12,1..2,1..6] OF REAL;
            TLKRESMAT:ARRAY[1..12,1..12] OF REAL;
            TNAMS:ARRAY[1..12] OF STROFTHREE;
            TLKNUM:INTEGER;
            END;

VAR
    CONDMEANS:FILE OF CONDREC;
    AFL,BFL,DRTTMPFL1,DRTEDA:TEXT;
    CONDLEN,ATTLEN,LNUM,I,NUM:INTEGER;
    CONDNUMSTRG,ATTSTRG:VARYING[1000] OF CHAR;
    COND:CONDREC;
    PAM:ARRAY[1..12,1..3,1..6] OF REAL;
    CNUM:CONDTYP;
    CH:CHAR;
    FLSNOTFOUND:INTEGER;
    NAMES,PERSONS:ARRAY[1..CREWNAMES] OF NAMTYP;
    CREW,COL,EDACOLS:INTEGER;
    NESTING,NESTMAX:ARRAY[1..DEPTHOFNESTING] OF INTEGER;
    LISNERMISSING:ARRAY[1..CREWNAMES] OF INTEGER;
    INDEX,LIDNUM:ARRAY[1..CREWNAMES] OF STROFTWO;
    REQUDLNRS:ARRAY[1..CREWNAMES] OF NAMTYP;
    EXPECTED_VALS_PER_LNR:INTEGER;
    PERCENT:REAL;

FUNCTION INTTOCHR(INTIN:INTEGER):STROFTWO;
(* turns integers(<99) into chars *)
VAR
```

```
    ICHRS:ARRAY[1..2] OF CHAR;
    ILOCSTRG:STROFTWO;
BEGIN
    ICHRS[1]:=CHR(48+(INTIN DIV 10));
    ICHRS[2]:=CHR(48+(INTIN REM 10));
    IF ICHRS[1]='0' THEN ICHRS[1]:=' ';
    PACK(ICHRS,1,ILOCSTRG);
    INTTOCHR:=ILOCSTRG;
    END;

FUNCTION CHRTOINT(CHIN:STROFTWO):INTEGER;
(* turns 2 char strings into integers *)
VAR
    INTOUT:INTEGER;
    CHRINTS:ARRAY[1..2] OF CHAR;
BEGIN
    UNPACK(CHIN,CHRINTS,1);
    IF CHRINTS[2]=' '
    THEN
        BEGIN CHRINTS[2]:=CHRINTS[1];CHRINTS[1]:='0' END;
    INTOUT:=(10*(ORD(CHRINTS[1])-48)) + (ORD(CHRINTS[2])-48);
    CHRTOINT:=INTOUT
END;

FUNCTION TOCHARS(LSNR:INTEGER;R:REAL):REALCHRS;
(* turns pos or neg real numbers i to chars of the form SAA.A *)
VAR
    IGER:INTEGER;
    CHRS:ARRAY[1..5] OF CHAR;
    LOCALSTR:REALCHRS;
BEGIN
    R:=(ROUND(R*10))/10;
    IF R=100 THEN TOCHARS:=' 100 '
             ELSE
             IF (R=0) AND (COND.LNAMS[LSNR]='----')
                 THEN TOCHARS:=' -999'
                 ELSE
                 BEGIN
                 IF R<0 THEN
                           BEGIN
                           CHRS[1]:='-';
                           R:=R*(-1)
                           END
                       ELSE CHRS[1]:=' ';
                 IGER:=TRUNC(R*10);
                 CHRS[2]:=CHR(48+(IGER DIV 100));
                 CHRS[3]:=CHR((48+(IGER DIV 10) REM 10));
                 CHRS[4]:='.';
                 CHRS[5]:=CHR(48+(IGER REM 10));
                 IF CHRS[2]='0' THEN CHRS[2]:=' ';
                 IF (CHRS[1]='-') AND (CHRS[2]=' ')
                 THEN
                     BEGIN
                     CHRS[1]:=' ';
```

```
                    CHRS[2]:='-'
                    END;
                PACK(CHRS,1,LOCALSTR);
                TOCHARS:=LOCALSTR
                END;
END;

PROCEDURE ENTERNAMES;
(* read listener names at start of each condition *)

VAR
    I,TIMESTHRU:INTEGER;
    MATCHED:BOOLEAN;

BEGIN
    FOR I:=1 TO 12 DO
        BEGIN
        TIMESTHRU:=1;
        READ(DRTTMPFL1,NAMES[I]);
        MATCHED:=FALSE;
        IF NAMES[I]<>'  ----'
        THEN
            BEGIN
            WHILE (NOT MATCHED) AND (TIMESTHRU<=CREW) DO
                IF NAMES[I] = PERSONS[TIMESTHRU]
                THEN
                    BEGIN
                    MATCHED:=TRUE;
                    INDEX[I]:=LIDNUM[TIMESTHRU]
                    END
                ELSE
                    TIMESTHRU:=TIMESTHRU+1;
            IF NOT MATCHED
            THEN    WRITELN('ERROR,    Unrecognised    listener    name:
',NAMES[I]);
            END;
        END;
    READLN(DRTTMPFL1);
END;


PROCEDURE UPDATE(VAR CURRENT,MAX : INTEGER);
BEGIN
    IF CURRENT<MAX
    THEN
        CURRENT:=CURRENT+1
    ELSE
        BEGIN
        CURRENT:=1;
        COL:=COL+1;
        UPDATE(NESTING[COL],NESTMAX[COL]);
        END;
END;
```

```
PROCEDURE OUTPTNESTING;

BEGIN
    COL:=1;
    UPDATE(NESTING[COL],NESTMAX[COL]);
    FOR I:=1 TO EDACOLS+1 DO WRITE(BFL,'    ',INTTOCHR(NESTING[I]));
END;


PROCEDURE TOEDAFORM;
(* reformat temp file to EDA format *)

VAR
    X,Y,I,J,K,L,CONDSETS,NUM,REQLNR,TEMP1:INTEGER;
    DATANAMES:VARYING[MAXDATASTRG] OF CHAR;
    TITLE:VARYING[MAXTITLESTRG] OF CHAR;
    DRT:NAMTYP;
    SCORE:ARRAY[1..12] OF NAMTYP;
    WHOBY:ARRAY[1..12] OF INTEGER;
    CH:CHAR;
    OK:BOOLEAN;
    REQULNRNUMS:ARRAY[1..12] OF STROFTWO;
    TEMP2:NAMTYP;

BEGIN
    (* read control file *)
    FOR I:=1 TO 10 DO READ(AFL,CH);
    READLN(AFL,REQLNR);
    FOR I:=1 TO REQLNR DO
        BEGIN
        READLN(AFL,REQUDLNRS[I]);
        LISNERMISSING[I]:=0;
        WHOBY[I]:=0
        END;
    READLN(AFL,CH);
    IF CH <> '*'
      THEN WRITELN ('ERROR ** Caused by incorrect number of listener
IDs');
    READLN(AFL);
    READLN(AFL,EDACOLS);
    READLN(AFL,DATANAMES);
    NESTMAX[1] := REQLNR;
    FOR I:=2 TO EDACOLS+1 DO
        READ(AFL,NESTMAX[I]);
    READLN(AFL);
    READLN(AFL,TITLE);
    READLN(AFL,CH);
    IF CH<>'*' THEN WRITELN('ERROR ** Caused by too many format
lines');
    REPEAT
        READLN(AFL,CH)
        UNTIL CH='*';
    FOR I:=1 TO 16 DO READ(AFL,CH);
    READLN(AFL,CREW);
```

```
    FOR I:=1 TO CREW DO
        READLN(AFL,PERSONS[I],CH,LIDNUM[I]);  (* read listener ids *)
    FOR I:=1 TO REQLNR DO                      (* note requd listener
ids *)
        FOR J:=1 TO CREW DO IF REQUDLNRS[I]=PERSONS[J] THEN
                                          REQULNRNUMS[I]:=LIDNUM[J];
    NESTING[1]:=0;
    FOR I:=2 TO EDACOLS+1 DO NESTING[I]:=1;
    WRITELN(BFL,INTTOCHR(EDACOLS+3));          (* write to opfile *)
    WRITELN(BFL,':"DRT    ","INDIV ","POSIT ",',DATANAMES);
    WRITELN(BFL,TITLE);
    RESET(DRTTMPFL1);
    CONDSETS:=1;
    FOR I:=3 TO EDACOLS+1 DO
        CONDSETS:=CONDSETS*NESTMAX[I];
    EXPECTED_VALS_PER_LNR:=NESTMAX[2]*CONDSETS;
    FOR I:=1 TO CONDSETS DO
        BEGIN
        ENTERNAMES;
        FOR J:=1 TO NESTMAX[2] DO
            BEGIN
            NUM:=1;
            FOR K:=1 TO 12 DO WHOBY[K]:=0;
            FOR K:=1 TO 12 DO
                BEGIN
                READ(DRTTMPFL1,DRT);
                OK:=FALSE;
                FOR L:=1 TO REQLNR DO IF NAMES[K]=REQUDLNRS[L]
                                      THEN OK:=TRUE;
                IF OK
                THEN
                    BEGIN
                    (* build up req listeners for sorting *)
                    SCORE[NUM]:=DRT;
                    WHOBY[NUM]:=CHRTOINT(INDEX[K]);
                    NUM:=NUM+1
                    END;
                END;
            (* check each req listener has a score *)
            WHILE (NUM-1)<REQLNR DO
                FOR X:=1 TO REQLNR DO
                    BEGIN
                    OK:=FALSE;
                    FOR Y:=1 TO (NUM-1) DO
                        IF WHOBY[Y]=CHRTOINT(REQULNRNUMS[X])
                        THEN OK:=TRUE;
                    IF NOT OK
                    THEN
                        BEGIN
                        WHOBY[NUM]:=CHRTOINT(REQULNRNUMS[X]);
                        SCORE[NUM]:='  -999';
                        LISNERMISSING[X]:=LISNERMISSING[X]+1;
                        NUM:=NUM+1
                        END;
```

```
                END;
            (* sort *)
            FOR K:=1 TO REQLNR-1 DO
                FOR L:=1 TO REQLNR-1 DO
                    IF WHOBY[L]>WHOBY[L+1]
                    THEN
                        BEGIN
                        TEMP1:=WHOBY[L];
                        WHOBY[L]:=WHOBY[L+1];
                        WHOBY[L+1]:=TEMP1;
                        TEMP2:=SCORE[L];
                        SCORE[L]:=SCORE[L+1];
                        SCORE[L+1]:=TEMP2
                        END;
            (* print *)
            FOR K:=1 TO REQLNR DO
                BEGIN
                WRITE(BFL,SCORE[K],'    ',INTTOCHR(WHOBY[K]));
                OUTPTNESTING;
                WRITELN(BFL)
                END;
            READLN(DRTTMPFL1);
            END;
        READLN(DRTTMPFL1);
        END;
    FOR I:=1 TO EDACOLS+3 DO WRITE(BFL,'-1 ');
    WRITELN(BFL);
    WRITELN(BFL,'-1');
END;

PROCEDURE DOEDAINPT;
(* create input file for panovun *)

VAR
    I:INTEGER;
    CH:CHAR;

BEGIN
    REWRITE(DRTEDA);
    RESET(AFL);
    FOR I:=1 TO 5 DO
        BEGIN
        CH:=' ';
        WHILE CH<>'*' DO READ(AFL,CH);
        READLN(AFL)
        END;
    READLN(AFL);
    CH:=' ';
    WHILE CH<>'*' DO
        BEGIN
        WHILE NOT EOLN(AFL) DO
            BEGIN
            READ(AFL,CH);
            IF CH<>'*' THEN WRITE(DRTEDA,CH)
```

```
            END;
        READLN(AFL);
        WRITELN(DRTEDA);
        END;
    END;


PROCEDURE OUTDATA(ATT:ATTYP);
(* decode attribute required and output *)

VAR
    LOCALARR:ARRAY[1..3] OF CHAR;
    TLKPOS,TPOS,TABNO,I,J:INTEGER;
    PAORM:CHAR;
BEGIN
    UNPACK(ATT,LOCALARR,1);
    PAORM:=LOCALARR[3];
    TABNO:=ORD(LOCALARR[1])+ORD(LOCALARR[2]);
    IF PAORM='P' THEN J:=1
                 ELSE IF PAORM='A' THEN J:=2
                                   ELSE J:=3;
    WITH COND DO
        CASE TABNO OF
             144:  BEGIN
                   FOR I:=1 TO 12 DO
                       WRITE(DRTTMPFL1,' ',TOCHARS(I,LISNEROAMS[I]));
                   END;
             165:  BEGIN
                   FOR I:=1 TO 12 DO
                       WRITE(DRTTMPFL1,' ',TOCHARS(I,PAM[I,J,1]));
                   END;
             143:  BEGIN
                   FOR I:=1 TO 12 DO
                       WRITE(DRTTMPFL1,' ',TOCHARS(I,PAM[I,J,2]));
                   END;
             168:  BEGIN
                   FOR I:=1 TO 12 DO
                       WRITE(DRTTMPFL1,' ',TOCHARS(I,PAM[I,J,3]));
                   END;
             156:  BEGIN
                   FOR I:=1 TO 12 DO
                       WRITE(DRTTMPFL1,' ',TOCHARS(I,PAM[I,J,4]));
                   END;
             153:  BEGIN
                   FOR I:=1 TO 12 DO
                       WRITE(DRTTMPFL1,' ',TOCHARS(I,PAM[I,J,5]));
                   END;
             146:  BEGIN
                   FOR I:=1 TO 12 DO
                       WRITE(DRTTMPFL1,' ',TOCHARS(I,PAM[I,J,6]));
                   END;
             159:  BEGIN
                   FOR I:=1 TO TLKNUM DO
                       BEGIN
```

```
                        FOR J:=1 TO 12 DO
                                                WRITE(DRTTMPFL1,'
',TOCHARS(J,TLKRESMAT[J,I]));
                        WRITELN(DRTTMPFL1);
                        END;
                    END;

        END;
        IF TABNO <> 159 THEN WRITELN(DRTTMPFL1);
END;

PROCEDURE SELECTDATA(COND:CONDREC);
(* write heading for block of data and loop thru attributes *)
(* calling OUTDATA.                                         *)

VAR
    ANUM:INTEGER;
    ATTREQ:ATTYP;
BEGIN
    FOR I:=1 TO 12 DO
        WRITE(DRTTMPFL1,'  ',COND.LNAMS[I]);
    WRITELN(DRTTMPFL1);
    ANUM:=4;
    REPEAT
        ATTREQ:=SUBSTR(ATTSTRG,ANUM-3,3);
        OUTDATA(ATTREQ);
        ANUM:=ANUM+4
        UNTIL ANUM > ATTLEN;
    WRITELN(DRTTMPFL1)
END;

PROCEDURE RETRIEVEREC(CONDNUMB:CONDTYP);
(* locate required conditions using EXPID as key, generate *)
(* means from Present and Absent, and call SELECTDATA      *)

VAR
    EXPID:PACKED ARRAY[1..7] OF CHAR;
    I,J,K:INTEGER;

BEGIN
    EXPID:='CTL'+CONDNUMB;
    COND.CONDITION:=EXPID;
    OPEN(CONDMEANS,
         HISTORY:=UNKNOWN,
         ORGANIZATION:=INDEXED,
         ACCESS_METHOD:=KEYED);
    RESETK(CONDMEANS,0);
    FINDK(CONDMEANS,0,COND.CONDITION);
    IF NOT UFB(CONDMEANS)
         THEN
         BEGIN
         READ(CONDMEANS,COND);
         FOR I:=1 TO 12 DO
             FOR K:=1 TO 6 DO
```

```
                BEGIN
                FOR J:=1 TO 2 DO
                    PAM[I,J,K]:=COND.ATTRIBUTES[I,J,K];
                PAM[I,3,K]:=(PAM[I,1,K]+PAM[I,2,K])/2;
                END;
          SELECTDATA(COND);
          END
          ELSE
          BEGIN
          WRITELN(EXPID,'** not found **');
          FLSNOTFOUND:=FLSNOTFOUND+1;
          WRITELN(DRTTMPFL1)
          END;
    CLOSE(CONDMEANS);

    END;



PROCEDURE DECODESTRGS;
(* decode string of conditions requd, and loop thru calling RETRIEVEREC
*)
VAR
    NUM1,NUM2,I:INTEGER;
    DELIM:PACKED ARRAY[1..1] OF CHAR;
    CONDARR,LASTARR:ARRAY[1..4] OF CHAR;
    ATTARR:ARRAY[1..2] OF CHAR;
    CONVS,CONDNUM,LASTNUM:CONDTYP;
BEGIN
    CONDLEN:=LENGTH(CONDNUMSTRG);
    ATTLEN:=LENGTH(ATTSTRG);
    LNUM:=1;
    REPEAT
          CONDNUM:=SUBSTR(CONDNUMSTRG,LNUM,4);
          DELIM:=SUBSTR(CONDNUMSTRG,LNUM+4,1);
          IF DELIM='-'
          THEN
              BEGIN
              LASTNUM:=SUBSTR(CONDNUMSTRG,LNUM+5,4);
              UNPACK(CONDNUM,CONDARR,1);
              UNPACK(LASTNUM,LASTARR,1);

NUM1:=1000+100*(ORD(CONDARR[2])-48)+10*(ORD(CONDARR[3])-48)
                                                    +ORD(CONDARR[4])-48;

NUM2:=1000+100*(ORD(LASTARR[2])-48)+10*(ORD(LASTARR[3])-48)
                                                    +ORD(LASTARR[4])-48;
              FOR I:=NUM1 TO NUM2 DO
                  BEGIN
                  CONDARR[4]:=CHR(48+(I REM 10));
                  CONDARR[3]:=CHR(48+((I REM 100) DIV 10));
                  CONDARR[2]:=CHR(48+((I REM 1000) DIV 100));
                  PACK(CONDARR,1,CONDNUM);
                  RETRIEVEREC(CONDNUM);
```

```
                END;
            LNUM:=LNUM+5;
            END
        ELSE
            RETRIEVEREC(CONDNUM);
        LNUM:=LNUM+5
        UNTIL LNUM > CONDLEN;
END;

BEGIN
OPEN(AFL,'infile',
      OLD);
RESET(AFL);
OPEN(BFL,'outfile');
REWRITE(BFL);
REWRITE(DRTTMPFL1);
CONDNUMSTRG:='';ATTSTRG:='';FLSNOTFOUND:=0;
FOR I:=1 TO 3 DO READLN(AFL);
READ(AFL,CH);
WHILE CH<>'*' DO
    BEGIN
    IF ORD(CH)=13 THEN CH:=',';
    ATTSTRG:=ATTSTRG+CH;
    READ(AFL,CH);
    END;
READLN(AFL);READLN(AFL);
READ(AFL,CH);
WHILE CH<>'*' DO
    BEGIN
    IF ORD(CH)=13 THEN CH:=',';
    CONDNUMSTRG:=CONDNUMSTRG+CH;
    READ(AFL,CH);
    END;
READLN(AFL);
FOR I:=1 TO 4 DO WRITELN;
WRITELN('OK, running DRTFILE');
WRITELN;
DECODESTRGS;
IF FLSNOTFOUND>0
THEN
    BEGIN
    WRITELN;
    WRITELN('Error!  **',FLSNOTFOUND:3,' files not found **');
    WRITELN;
    END
ELSE
    BEGIN
    WRITELN('OK, all records found, creating output file');
    WRITELN;
    TOEDAFORM;
    WRITELN('OK, output file created');
    WRITELN;
    FOR I:=1 TO CREW DO
        IF LISNERMISSING[I]>0
```

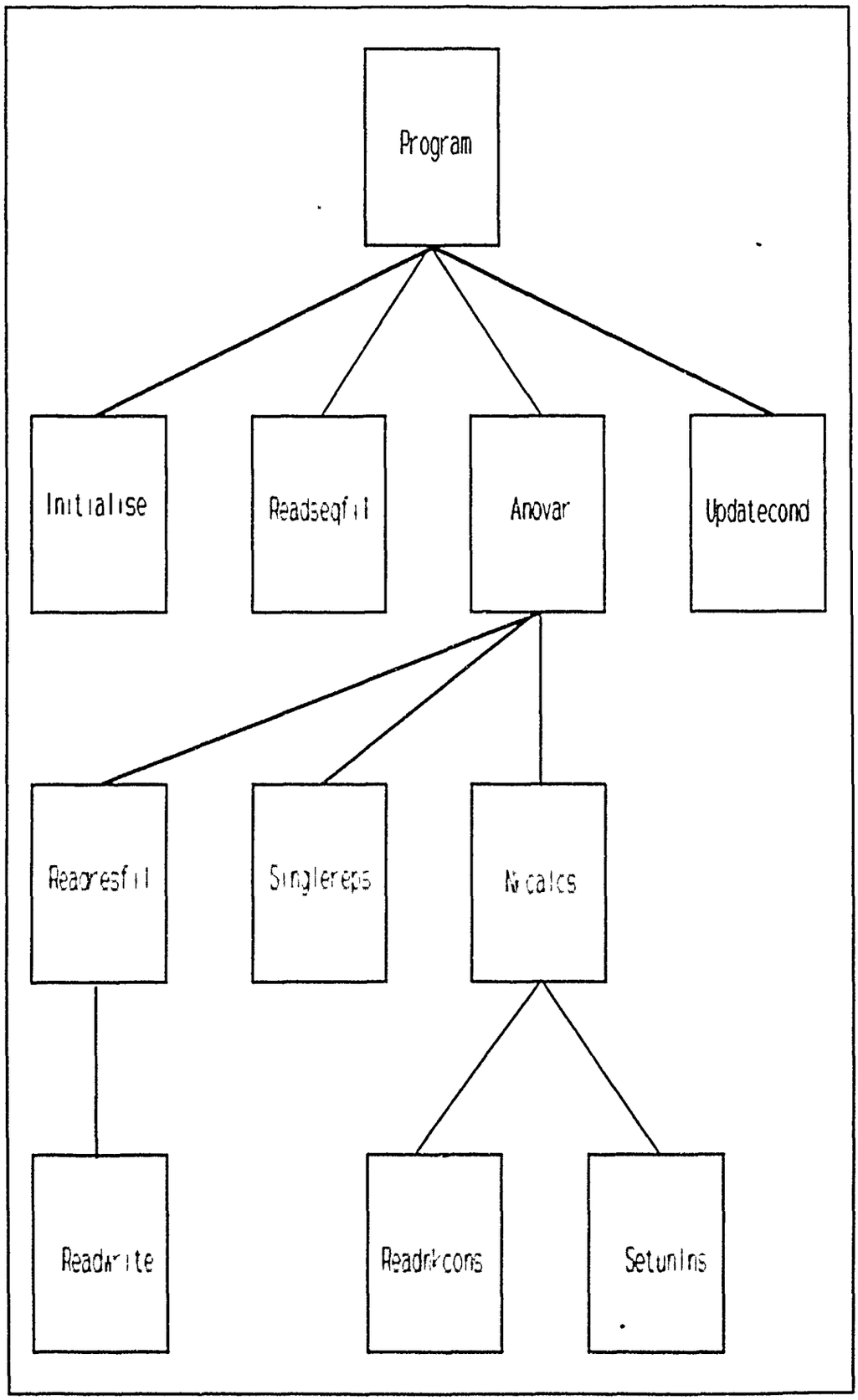
```
        THEN
            BEGIN
            PERCENT:=(LISNERMISSING[I] / EXPECTED_VALS_PER_LNR)*100;

            WRITELN('Warning ,',REQUDLNRS[I],' has ',
                  LISNERMISSING[I]:3,'   (',PERCENT:3:1,'%)   missing
values');
            END;
    DOEDAINPT;
    END;
END.
```

```
PROGRAM DRTEDIT(INPUT,OUTPUT,CONDMEANS);

TYPE
    CONDTYP=PACKED ARRAY[1..4] OF CHAR;
    CONDNAMETYP=PACKED ARRAY[1..7] OF CHAR;
    STROFTHREE=PACKED ARRAY[1..3] OF CHAR;
    ARROFMEANS=ARRAY[1..12] OF REAL;
    CONDREC=RECORD
            CONDITION:[KEY(0)] PACKED ARRAY[1..7] OF CHAR;
            LNAMS:ARRAY[1..12] OF CONDTYP;
            LISNEROAMS:ARROFMEANS;
            ATTRIBUTES:ARRAY[1..12,1..2,1..6] OF REAL;
            TLKRESMAT:ARRAY[1..12,1..12] OF REAL;
            TNAMS:ARRAY[1..12] OF STROFTHREE;
            TLKNUM:INTEGER;
            END;

VAR
    CONDMEANS:FILE OF CONDREC;
    CHOICE:INTEGER;
    COND:CONDREC;

PROCEDURE DISPINDEX;
    VAR
        WRITS:INTEGER;
        NUM:CONDTYP;
    BEGIN
    WRITELN;
    RESET(CONDMEANS);
    WRITS:=-1;
    WHILE NOT EOF(CONDMEANS) DO
        BEGIN
        READ(CONDMEANS,COND);
        NUM:=SUBSTR(COND.CONDITION,4,4);
        WRITS:=WRITS+1;
        IF WRITS>12
        THEN
            BEGIN
            WRITELN;
            WRITS:=0
            END;
        WRITE(NUM,'  ');
        END;
    WRITELN;
    CLOSE(CONDMEANS);
    END;

PROCEDURE DELENTRY;
    VAR
        CNUM:CONDTYP;
        EXPID:CONDNAMETYP;
    BEGIN
    OPEN(CONDMEANS,
         HISTORY:=UNKNOWN,
```

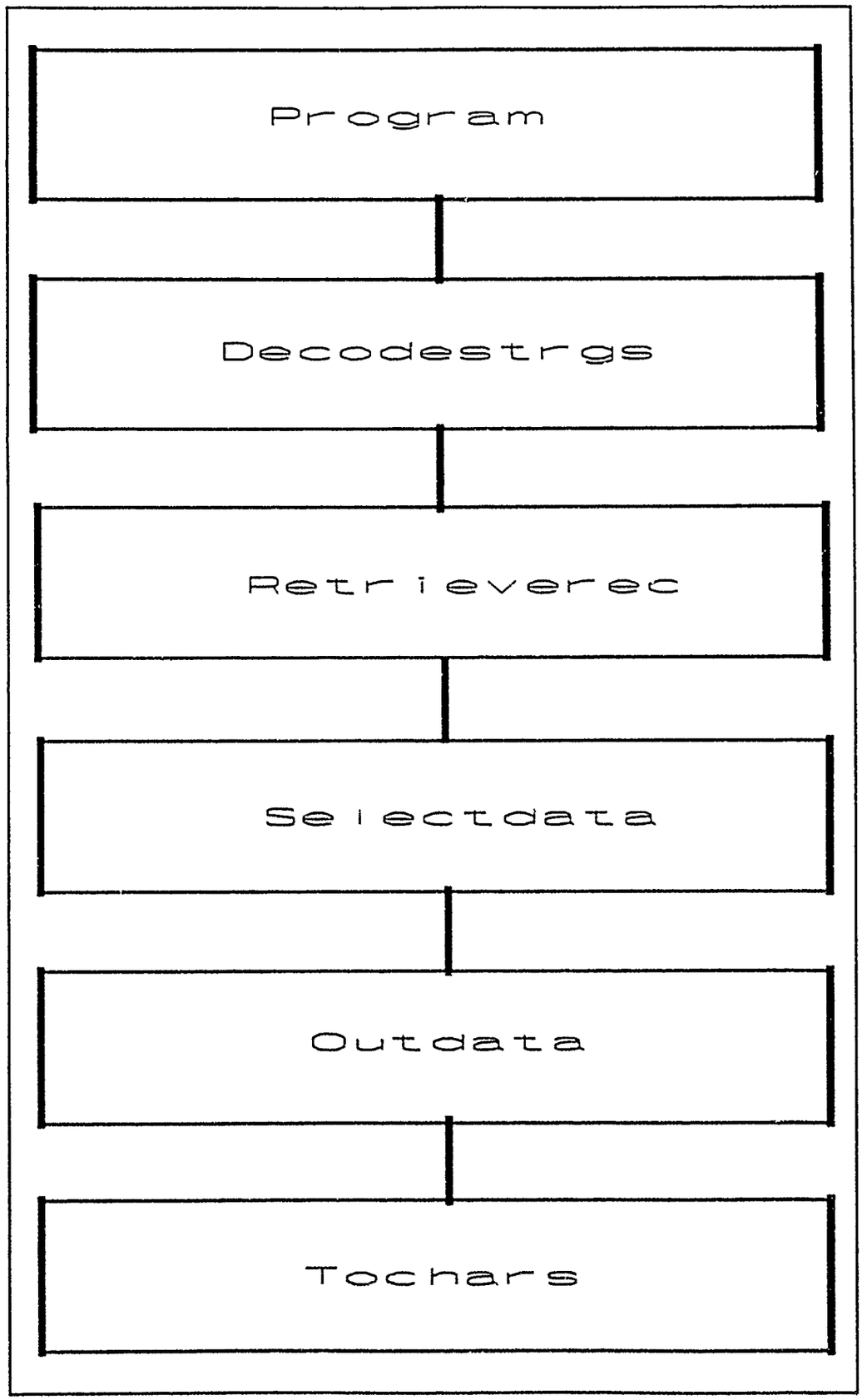
```
          ORGANIZATION:=INDEXED,
          ACCESS_METHOD:=KEYED);
    WRITE('Enter Condition Number to be Deleted: ');
    READLN(CNUM);
    EXPID:='CTL'+ CNUM;
    FINDK(CONDMEANS,0,EXPID);
    IF NOT UFB(CONDMEANS)
    THEN
        BEGIN
        DELETE(CONDMEANS);
        WRITELN(EXPID,' deleted OK')
        END
    ELSE
        WRITELN('Condition ',EXPID,' not on file');
    CLOSE(CONDMEANS)
    END;

PROCEDURE DISPMENU;
    BEGIN
    WRITELN;
    WRITELN('DRTEDIT');
    WRITELN('--------');
    WRITELN;
    WRITELN('1. Display Index');
    WRITELN('2. Delete an entry');
    WRITELN('3. End');
    WRITELN;
    WRITE('Select.. ');
    END;

BEGIN
    CHOICE:=0;
    WHILE CHOICE<>3 DO
        BEGIN
        DISPMENU;
        READLN(CHOICE);
        CASE CHOICE OF
           1: DISPINDEX;
           2: DELENTRY;
           END;
        END;
END.
```

A2 Program Structure Charts

DRTSTAT.PAS



DRTFILE.PAS


Program
Decodestrgs
Retrieverec
Selectdata
Outdata
Tochars

A3 Sample Program Outputs

Output from DRT1.COM

```
DRT STATISTICS PROGRAM
----------------------

Enter filename: Enter filename: CND3139

Control File: CTL3139

Source: Multi-Listener Master V4
Date:   9-NOV-89

Input Device:  B&K WB TAPE
Input Noise:   NONE
Link Device:   SPECIAL CODER
Output Device: BT HANDSET
Output Noise:  65DB(A)USASI

! Optional Header Text
HANDSET TEST
TAPE 8
Sequence Type:  DYNA
Filler Display: Enabled

Words File:     DYNAWRD
Sequences File: DYNASEQ

DRTs:  10
! Talker        List
RLP             306A.1
RLP             306A.2
RB              308A.1
RB              308A.2
MCL             315A.1
MCL             315A.2
PRW             312A.1
PRW             312A.2
GAP             314A.1
GAP             314A.2
Listeners: 10
! Listener  Station
ABBOTT          1
BERRY           2
BLACK           3
MCINTOSH        4
RUSBY           5
HOOK            6
JON1            7
TAYLOR          8
JON2            9
SLATER          10
```

TUKEY TEST FOR NONADDATIVITY

Source	Sum of Squares	Degrees of Freedom	Mean Square
LISNERS	477.09	9	53.01
TALKERS	624.88	4	156.22
RESIDUAL	460.19	36	
NONADD	3.38	1	3.38
BALANCE	456.81	35	13.05

ANALYSIS OF VARIANCE

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-Ratio
LISNERS	954.25	9	106.03	1.99
TALKERS	1249.75	4	312.44	5.87
LN * TK	920.38	36	25.57	0.48
ERROR	2660.56	50	53.21	
TOTAL	5784.94	99		

NEWMAN - KEULS TEST

LISTENERS :

2 3 8 4 6 1 10 9 7 5

TALKERS :

4 3 5 1 2

ATTRIBUTE SCORES

	Present		Absent		Mean	
	mean	SE	mean	SE	mean	SE
Voicing	87.5	2.5	70.5	4.7	79.0	3.2
Nasality	96.5	0.6	84.3	3.5	90.4	2.2
Sustention	72.8	2.8	69.3	2.8	71.0	2.0
Sibilation	82.5	1.9	81.5	2.2	82.0	1.4
Graveness	61.0	2.4	62.3	2.8	61.6	1.8
Compactness	90.0	2.6	80.5	3.9	85.3	2.5

INDIVIDUAL SCORES

LNR	T1	T2	T3	T4	T5	SD
1	79.2	82.3	72.9	76.0	86.5	5.3
2	76.0	80.2	67.7	61.5	71.9	7.3
3	82.3	78.1	72.9	70.8	71.9	4.9
4	77.1	81.3	76.0	80.2	76.0	2.4
5	84.4	86.5	76.0	78.1	86.5	4.9
6	83.3	82.3	76.0	77.1	78.1	3.2
7	84.4	85.4	77.1	68.8	88.5	8.0
8	75.0	80.2	79.2	65.6	77.1	5.8
9	83.3	81.3	76.0	76.0	85.4	4.3
10	81.3	83.3	76.0	76.0	81.3	3.3

LNR	MEAN OVER TKR
1	79.4
2	71.5
3	75.2
4	78.1
5	82.3
6	79.4
7	80.8
8	75.4
9	80.4
10	79.6

STD. DEVN. = 3.3
STD. ERROR = 1.0

TKR	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	SD
1	79.2	76.0	82.3	77.1	84.4	83.3	84.4	75.0	83.3	81.3	3.5
2	82.3	80.2	78.1	81.3	86.5	82.3	85.4	80.2	81.3	83.3	2.5
3	72.9	67.7	72.9	76.0	76.0	76.0	77.1	79.2	76.0	76.0	3.1
4	76.0	61.5	70.8	80.2	78.1	77.1	68.8	65.6	76.0	76.0	6.1
5	86.5	71.9	71.9	76.0	86.5	78.1	88.5	77.1	85.4	81.3	6.2

TKR	MEAN OVER LNR
1	80.6
2	82.1
3	75.0
4	73.0
5	80.3

STD. DEVN. = 4.0
STD. ERROR = 1.8

DRT SCORE = 78.2
STANDARD ERROR = 1.0

Output from DRT2.COM (written to DRTTMPFL2.DAT)

```
 5
:"DRT    ","INDIV ","POSIT ","ATTR","COND"
TITLE
  62.5       14       1       1       1
  75.0       14       1       2       1
  75.0       14       1       3       1

etc...

  75.0       15       2       4       4
  46.9       15       2       5       4
  75.0       15       2       6       4
    -1       -1      -1      -1      -1
    -1
```

Output from DRT3.COM

```
CCF> @drt3

DRTEDIT
-------

1. Display Index
2. Delete an entry
3. End

Select.. 1
      1191  1192  1193  1194  1195  1196  1197  1199  1200  1201  1202
1203  1204  1205  1206  1207  1208  1219  1220  1221  1222  1223  1224
1225  1226  1227  1228  1229  1230  1231  1232  1233  1234  1235  1236
1237  1238  1239  1240  1241  1242  1243  1244  1245  1246  1247  1248
1249  1250  1251  1252  1253  1254  1255  1256  1257  1258  1259  1260
1261  1262  1263  1264  1265  1266


DRTEDIT
-------

1. Display Index
2. Delete an entry
3. End

Select.. 3
```

A4 Sample Control File for DRT2

Example Control File (CF....)

```
! This file is for EXAMPLE purposes only, and will not run.
! Lines starting with ! are used for comment here, but will cause fatal
errors at runtime.
!
! Make the control file name the same as the filename used to store
this file
!
! N.B.!!!  The "star" symbols must seperate the different entries.
!
Control File: CFwhatever
*
!
! These numbers after the colon must tally with the number of lines
below them.
!
Attributes:1
TKR
*
! List CND numbers here. These are in the order corresponding to the
! Design statement used in PANOVUN.
!
Conditions:24
1338
1349
1342
1353
1335
1348
1334
1345
1331
1344
1339
1352
1337
1350
1341
1354
1336
1347
1333
1346
1332
1343
1340
1351
*
!
! Select listeners whose results you wish to use.
! Some degree of " missing values" (less than 10%) is acceptable
```

```
! YOU MUST LEAVE TWO SPACES in front of the four letter name.
!
Listeners:12
  CHAM
  PRAT
  WHEA
  SLAT
  PAWS
  BERR
  FERR
  PERK
  SIMO
  KNUT
  TAYL
  PLOW
*
!
! First line is ALWAYS "Format:4"
! Second line is the number of variables.
! Third line is the nesting of the variables.
! Fourth line is the quantity of each of the variables.
! Fith line is a title that will appear on the printout.
!
Format:4
5
"TALKER","REPLIC","UTTER ","CODER ","SNR    "
5 2 2 3 2
Title line
*
!
! These statements drive PANOVUN, an analysis of variance program
! Written by the Institute of Aviation medecine.
!
Anovar Design:-
Another title
Y
1
N
:E
1
E
D Put your design statement here
A(IY,V=-999)DRT
E
Q
*
!
! Listener ident. numbers are put here.
! Last listener is always "-----"
! Further listeners may be added as required.
! BUT LEAVE TWO SPACES
!
!
!
```

```
Listener Idents:14
  CHAM 1
  PRAT 2
  WHEA 3
  SLAT 4
  PAWS 5
  BERR 6
  FERR 7
  PERK 8
  SIMO 9
  KNUT 10
  TAYL 11
  PLOW 12
  ROBE 13
  ----- 14
*
```

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Abstract

This report describes the statistical techniques and associated computer programs employed to analyse data obtained from Diagnostic Rhyme Tests (DRT), and was previously published as a Divisional Memorandum. The conduct of the DRT (used for quantifying speech intelligibility) was described in RSRE Report No 87003.

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